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SECTION I.
HOMEWORK ASSIGNMENTS
**Homework #1—Principles of Industrial Hygiene**

**Background:**

This exercise is designed to familiarize the student with various reference sources available to the Safety Professional in the area of industrial hygiene references sources. To complete this exercise, you will need to refer to the textbook and library catalog. Additional web-based resources may be used to assist in the completion of this exercise.

**Practical Exercise #1:** Use the *Fundamentals of Industrial Hygiene* 6th edition (*FIH 6e*) to complete the following.

1. Use Appendix A to complete the table. Identify the organization that each acronym stands for, and denote the type by recording the corresponding letter for each organization: Professional (P), Scientific& Service (SS), U.S. Government Agency (G), Industry (I) or Labor Union (LU).

<table>
<thead>
<tr>
<th>Organization</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. AIHA</td>
<td></td>
</tr>
<tr>
<td>b. ABIH</td>
<td></td>
</tr>
<tr>
<td>c. ASSE</td>
<td></td>
</tr>
<tr>
<td>d. BCSP</td>
<td></td>
</tr>
<tr>
<td>e. NFPA</td>
<td></td>
</tr>
<tr>
<td>f. ANSI</td>
<td></td>
</tr>
<tr>
<td>g. NSC</td>
<td></td>
</tr>
<tr>
<td>h. UL</td>
<td></td>
</tr>
<tr>
<td>i. OSHA</td>
<td></td>
</tr>
<tr>
<td>j. UFW</td>
<td></td>
</tr>
<tr>
<td>k. ANSI</td>
<td></td>
</tr>
<tr>
<td>l. ASHRAE</td>
<td></td>
</tr>
<tr>
<td>m. SME</td>
<td></td>
</tr>
<tr>
<td>n. NIOSH</td>
<td></td>
</tr>
<tr>
<td>o. ACGIH</td>
<td></td>
</tr>
<tr>
<td>p. ISEA</td>
<td></td>
</tr>
<tr>
<td>q. UMWA</td>
<td></td>
</tr>
<tr>
<td>r. APHA</td>
<td></td>
</tr>
</tbody>
</table>
2. Professional Safety Certifications: Use Chapter 24 to identify the professional designation for which the following acronyms stand.
   a. ASP:
   b. CSP:
   c. CIH:
   d. CHP:
   e. PE:

3. Using Appendix B, define the following terms and give the full meaning of each.
   a. TLV-TWA:
   b. TLV-C:
   c. TLV-STEL:
   d. Skin Notation:
   e. BEI’S:
   f. PNOC:
   g. Mixture:
   h. Unlisted Substances:

4. Using Appendix B, complete the following:
   a. What is the time-weighted average (TWA) and short term exposure limit (STEL) for the following chemicals?

<table>
<thead>
<tr>
<th>Chemical</th>
<th>TWA (ppm)</th>
<th>STEL (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turpentine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   b. What is the TWA for Asbestos? ________________

   c. What is the CAS # for Benzene? ____________________
d. Is GYPSUM a PNOC? Yes___ No _____
e. What is a carcinogen? ______________________________________

f. List the categories for carcinogenicity found in Appendix B and describe them:
   1. 
   2. 
   3. 
   4. 
   5. 

5. Using Appendix D, complete the following.

a. Determine the number of significant digits:

<table>
<thead>
<tr>
<th>Number</th>
<th>Significant digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0702</td>
<td></td>
</tr>
<tr>
<td>69.20</td>
<td></td>
</tr>
<tr>
<td>7020</td>
<td></td>
</tr>
</tbody>
</table>

b. Provide the value for the expression

<table>
<thead>
<tr>
<th>Expression</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 x 10^5</td>
<td></td>
</tr>
<tr>
<td>10^5</td>
<td></td>
</tr>
<tr>
<td>Log 10</td>
<td></td>
</tr>
<tr>
<td>Log 1000</td>
<td></td>
</tr>
<tr>
<td>6 x 10^8</td>
<td></td>
</tr>
<tr>
<td>1 x 10^7</td>
<td></td>
</tr>
<tr>
<td>Log 100</td>
<td></td>
</tr>
<tr>
<td>Log 10^9</td>
<td></td>
</tr>
</tbody>
</table>
6. Using Appendix D, define the following:

a. HEPA:

b. LD₅₀:

c. SCBA:

d. IAQ:

e. IDLH:

f. LC₅₀:

7. Use the Index and Glossary to find the following acronyms and define them.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Page #</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSHA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOAEL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Practical Exercise #2:** Use the university library catalog to determine the library location of the following publications.

<table>
<thead>
<tr>
<th>Title</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sax’s Dangerous Properties of Industrial Materials</td>
<td>R 604.7 SA9D7 - Reference</td>
</tr>
<tr>
<td>Patty’s Industrial Hygiene &amp; Toxicology</td>
<td></td>
</tr>
<tr>
<td>AIHA Journal</td>
<td></td>
</tr>
<tr>
<td>Professional Safety Journal</td>
<td></td>
</tr>
<tr>
<td>The Occupational Environment: Its Evaluation, Control, and Management</td>
<td></td>
</tr>
<tr>
<td>Encyclopedia of Occupational Health and Safety</td>
<td></td>
</tr>
<tr>
<td>Fundamentals of Industrial Hygiene</td>
<td></td>
</tr>
<tr>
<td>Definitions, Conversions, and Calculations for Occupational Safety and Health Professionals</td>
<td></td>
</tr>
</tbody>
</table>
Practical Exercise #3: Convert the following to the designated units.

1. \(32 ^\circ C = \___ ^\circ F\)
2. \(100 ^\circ C = \___ ^\circ F\)
3. \(0 ^\circ C = \___ ^\circ F\)
4. \(-40 ^\circ C = \___ ^\circ F\)
5. \(32 ^\circ F = \___ ^\circ C\)
6. \(100 ^\circ F = \___ ^\circ C\)
7. \(0 ^\circ F = \___ ^\circ C\)
8. \(-40 ^\circ F = \___ ^\circ C\)
9. \(25 ^\circ C = \___ ^\circ K\)
10. \(100 ^\circ C = \___ ^\circ K\)
11. \(0 ^\circ C = \___ ^\circ K\)
12. \(-10 ^\circ C = \___ ^\circ K\)
13. \(32 ^\circ F = \___ ^\circ K\)
14. \(100 ^\circ F = \___ ^\circ K\)
15. \(0 ^\circ F = \___ ^\circ K\)
16. \(-40 ^\circ F = \___ ^\circ R\)
17. \(32 ^\circ F = \___ ^\circ R\)
18. \(100 ^\circ F = \___ ^\circ R\)
19. \(0 ^\circ F = \___ ^\circ R\)
20. \(-460 ^\circ F = \___ ^\circ R\)
21. \(1 \text{ in} = \___ \text{ft.}\)
22. \(12 \text{ in} = \___ \text{ft.}\)
23. \(144 \text{ in} = \___ \text{yd}\)
24. \(30 \text{ ft.} = \___ \text{yd}\)
25. \(4 \text{ ft.} = \___ \text{in}\)
26. \(1 \text{ ft.} = \___ \text{M}\)
27. \(4 \text{ ft.} = \___ \text{M}\)
28. \(5 \text{ in} = \___ \text{cm}\)
29. \(3 \text{ ft.} = \___ \text{cm}\)
30. \(40 \text{ cm} = \___ \text{mm}\)
31. \(8 \text{ cm} = \___ \text{mm}\)
32. \(5 \text{ M} = \___ \text{cm}\)
33. \(0.5 \text{ M} = \___ \text{cm}\)

Abbreviations:

\( ^\circ C \) = degrees Celsius  \( ^\circ F \) = degrees Fahrenheit
\( ^\circ K \) = degrees Kelvin
in = inches
ft. = feet
yd = yard
M = meters
\( \text{cm} = \text{centimeters} \)
\( \text{mm} = \text{millimeters} \)
\( \text{L} = \text{liters volume} \)
\( \text{M}^3 = \text{meters cubed volume} \)
\( \text{ml} = \text{milliliters volume} \)
\( \text{Atm} = \text{atmospheres of pressure} \)
\( \text{mmHg} = \text{millimeters of mercury pressure} \)

\( \text{PSI} = \text{pounds per square inch pressure} \)
Homework #2—Laboratory Writing Exercise

Background:
This exercise is designed to familiarize the student with the laboratory report writing process, i.e., converting raw data into a report form. To complete this exercise, you will need to pull a reference article from an occupational hygiene or safety journal that contains data, review the provided laboratory write up outline (below) and paraphrase the article into the same format.

I. Selection of article: Requirements
   a. The article must contain laboratory data.
   b. The article must be related to the practice of industrial hygiene.
   c. The article must be from a peer reviewed journal.

II. Write-up
   a. Reformat the article to fit the lab write-up template. Below is a guide to help you determine where the information is most likely located in the article. (Note: This is a general guideline as not all journals follow the same format.)
      i. Purpose: Introduction section of article
      ii. Theory: Introduction section of article
         or (depending on instructor)
         Materials: Listing all materials used for research in article
      iii. Procedure: Materials and methods section of article
      iv. Results: Results section of article
      v. Discussion: Discussion section of article
      vi. Conclusion: Discussion section of article, usually the final paragraph or in a separate conclusion section
      vii. References: References section of article
      viii. Appendix: Attach article here.

Note: The length of your write-up will vary based on the article selected. You will need to include a copy of the article with the write-up in the appendix. Only for this write-up, by design, your work will be based on the article. You do not need to worry about direct quote versus paraphrasing of material. For all other write-ups, you will need to provide the reference(s) in an appropriate format.
SECTION II. LABS

Laboratory #1
Personal Protective Equipment
Laboratory #1—Personal Protective Equipment

Background:

The National Institute of Occupational Safety and Health (NIOSH) does not recommend using Chemical Protective Clothing (CPC) as a first choice for preventing skin contact (Roder, 1990). NIOSH believes that CPC should be considered as the last line of defense to protect against accidental contact (e.g., spills, splashes). This is in conformance with the generally accepted industrial hygiene strategy for controlling workplace exposures to chemical hazards, which recommends, beginning with the highest preference, the following hierarchy of primary controls: (1) substitution or elimination, (2) process change, (3) isolation/enclosure, (4) ventilation, (5) good housekeeping, and (6) personal protection (Birmingham, 1991). This hierarchy of controls is similarly supported by the Occupational Safety and Health Administration (OSHA) (1997). In addition, three secondary means of preventing exposure and occupational illness include: (1) education and training of management, first-line supervisors, and employees; (2) medical surveillance programs; and (3) environmental monitoring. With this strategy, all chemical hazards, including those that primarily involve potential contact with the skin because of aerosol impingement or direct contact, may be effectively controlled. Experience indicates that choosing CPC as a first choice of protection is not prudent as it is likely to be the least reliable in providing consistent, dependable protection.

Should the safety professional decide that Personal Protective Equipment (PPE) is necessary, the first step in the process is determining the level of personal protection necessary for personnel who will be working at the site. It is the Safety Professional’s duty to select the type of PPE appropriate for the specific site and situation. The equipment and clothing selected must provide an adequate level of protection for a specific situation. For the approximately 450 organic substances recommended in the NIOSH Pocket Guide to protect the skin (skin notation), a recommendation for specific glove material could be provided for only 39%. For those substances where a glove type was recommended, 47% of the recommendations for glove material were for PE/EVAL co-laminate, Teflon® or Viton® polymers. Unfortunately, these latter materials are either uncomfortable to wear, lack good tactility, are fragile and expensive, or (as in the case of Teflon) are presently difficult to purchase. Polyvinyl alcohol (PVA) polymer offers excellent resistance against many organic substances but is highly sensitive to degradation by water and may be ineffective for extended use where perspiration occurs. A glove material such as natural rubber, polyvinyl chloride, butyl rubber, nitrile, or neoprene is suggested for less than 21% of the organic substances listed in the Pocket Guide where preventing skin contact is recommended. For many organic substances that may be potential skin exposure hazards, no recommended barrier for hand protection can be presently provided.

The principal reason why a specific glove material type is not provided for over 60% of the chemicals for which skin protection is recommended is due to the limitations of the American Society for Testing and Materials (ASTM) Method F739. In its most common applications, Method F739 is limited to chemicals with vapor pressures of at least 0.1 mm Hg and up to 10 mm Hg, depending on modifications to the method, or to chemicals that are water soluble so that the permeant can be collected in a gaseous or aqueous receptor stream, respectively (ASTM, 1999). However, modifications to optimize the method have suggested that
toxic chemicals with very low vapor pressures will permeate most CPC materials within a short time, albeit perhaps not at the same mass flux rate as more volatile substances (Fricker and Hardy, 1992). Chemicals with low volatility may readily penetrate the skin barrier, be highly toxic, and tend to bio-accumulate within exposed persons over time. Thus, even small amounts of CPC breakthrough could carry a health concern.

For chemicals that exist as a powder, flake, or solid at room temperature, guidance for selecting appropriate CPC materials is generally not available because of the technical difficulties of testing membranes against such substances. It may not be prudent to assume that the chemical cannot substantially solubilize into a CPC polymer membrane or that the dry chemical will never become moistened, both potentially resulting in enhanced permeation through the barrier. If the chemical is capable of affecting the skin or causing systemic effects, a good chemical protective barrier should be worn, regardless of its physical state. A review of the literature and possible approaches to testing gloves using solid sorbents as collection media has been recently proposed to objectively determine the adequacy of CPC performance. Additional testing results are needed regarding the effectiveness of CPC membranes against substances not previously tested.

Another problem with the published permeation data is that great inconsistencies in glove performance are sometimes reported for substances with similar chemical properties (e.g., dimethylamine, diethylamine), and a wide range of test values may be reported by different laboratories for similar glove materials. This is likely to be explained in part by the apparent inconsistent composition of manufactured gloves (Mickelsen and Hall, 1987; Perkins and Pool, 1997; Oppl, 2001a). Kinetic testing data reported on a specific barrier membrane from one manufacturer, and even from different lot batches, may differ substantially and may not be representative of all such membranes from different sources. Imperfections during manufacturing, resulting in thin areas and even small holes that can allow penetration through the membrane have been found in gloves meant to be used for both single use and longer term chemically resistant use (Canning et al. 1998; Dashner and Habel 1988; Sansone and Tewari 1978). Imprecision in laboratory testing has also been cited to contribute to some of the variance in reported permeation results, which may vary up to 50% between laboratories (Oppl 2001b).

In selecting CPC materials, the user is also confronted with the fact that the actual use conditions of the CPC is likely to be different than the testing conditions used in the laboratory. Multiple variables present in actual use that are dissimilar to typical laboratory testing conditions might include higher working temperatures, mechanical stresses, and exposure to chemical mixtures. Cost and human factors, such as the need for tactility when performing a job, are also important considerations. In many cases, a glove with the longest breakthrough time may not necessarily be the most practical choice. More frequent changes but better usability may be an acceptable trade-off for choosing a glove with a shorter breakthrough time (Klingner and Boeniger forthcoming). Over extended periods of use, gloves will likely become contaminated on the inside by repeated doffing and donning (Garrod et al. 1999; Garrod et al. 2001; Kusters 1992; Sanderson et al. 1995).

The purpose of this laboratory exercise is to show students how to shield or isolate individuals from the chemical, physical, and biological hazardous waste. PPE should protect the respiratory system, skin, eyes, hands, face, feet, head, body, and hearing as specified under OSHA 29 CFR, Part 1910 and EPA 40 CFR, Part 300.
See Chapter 23 for additional information for each exercise.

Safety Goggles and Glasses
Employees need protective glasses, goggles, or masks for protection against hazards including fine particles and chemical and injurious light rays. Glasses and goggles used to protect eyes should have lenses that can withstand (without shattering) the impact of a 7/8 inch steel ball dropped 50 inches. Lenses that have passed this test are labeled by manufacturers as meeting the ANSI Z 87.1 standard which is commonly known as Z 87.1.

Figure 1 (page 15) gives a variety of different types of safety glasses and goggles and the recommended protector for different applications.

Acetylene
Burning, cutting, and welding cause sparks, harmful rays, molted metal, and flying particles. The recommended protectors are Numbers 7, 8, and 9. Number 7 is welding goggles, eyecup type, with tented lenses. Number 8, is welding goggles, cover spec type, tented lenses. Number 9 is also used for welding. These goggles are cover spec type and have a tented plate lens.

Chemical Handling
Some hazards might include splash, acid burns, and fumes. The recommended protectors are Numbers 2 through Number 10, (for severe exposures add 10 over 2). Number 2 is a flexible fitting goggle, with hooded ventilation. Number 10 has a face shield, which is available with a plastic or mesh window.

Chipping
For the flying particles hazard, recommended protectors are Numbers 1, 3, 4, 5, 6, 7A, and 8A. Number 1 goggles are flexible fitting with regular ventilation. Number 2 goggles are flexible fitting hooded ventilation. Number 3 goggles are cushioned fitting with a rigid body. Number 4 are spectacles with a metal frame and side-shields. Number 5 spectacles have a plastic frame with side-shields. Number 6 spectacles are metal with a plastic frame and side shields. (Number 7A are chipping goggles. They are eyecup type, C clear safety lens but are not shown. Number 8A are chipping goggles, cover spec type, clear safety lens, and they are also not shown.)

Electric Arc Welding
The hazards are sparks, intense rays, and molten metal. The recommended protectors are 9 and 11. Number 9 are welding goggles, cover spec type, and tented plate lens. Number 11 is a welding helmet.

Grinding
The hazard might be chemical splashes or glass breakage. The recommended protectors are Numbers 2 and 10 when in combination with Numbers 4, 5, or 6.
Machining  
Hazards are flying particles. The recommended protectors are Numbers 1, 3, 4, 5, 6, and 10.

Safety Boots and Shoes  
All employees exposed to occupational risks of foot injuries need safety boots, shoes, or protective shoe caps. Examples of operations where safety shoes should be worn are construction sites, warehouses, lumber mills, and scrap-metal yards. Safety shoes should have reinforced steel toe caps capable of protecting the toe from a static compression of 2500 pounds and from the impact of a 50-pound weight dropped from 18 inches.

Hard Hats  
All employees exposed to flying or falling objects and/or electrical shocks and burns need safety hats or hard hats. For safe exposure to flying or falling objects, the hard hat must comply with American National Standards Institute Z 89.1 - 1969. For exposure to a shock of 600 volts and burns, the hard hat should comply with American National Standards Institute Z 89.1 - 1969. For exposure to a voltage shock of more than 600 volts and burns, the hard hat should comply with ANSI Z 89.2 - 1972. The top of the hard hat and the strap on top of your head must have a safety zone. This zone is a buffer, a shock absorber that will protect your head on impact. The safety zone must be 1 1/4 inches. This means a gap of 1 1/4 inches must be above your head and the top of the hard hat.

If you encounter a shock, the proper class of hard hat must be worn. Class A and Class D hard hats will protect against an exposure to high voltage shock of 600 volts or less. Class B hard hats protect against voltage shock of more than 600 volts. The hard hat not only helps protect against burns, but it also aids in the likely event of a fall from the shock.

There is no single piece of protective equipment or any combination of equipment that clothing is capable of protecting against all hazards. PPE must be used in conjunction with other protective methods. Some problems with PPE are that they can cause heat stress, physiological stress, impaired vision, mobility, and impaired communication.

Eye and Face Protection

Criteria
- Protect against specific hazard(s) encountered by employees
- Comfortable to wear
- Must not restrict vision or movement
- Durable and easy to clean and disinfect
- Must not interfere with the function of other required PPE
- Meet requirements of ANSI Z87.1-1989 for devices purchased after July 5, 1994, and ANSI Z87.1-1968 for devices purchased before that date

Eye Protection for Employees Who Wear Eyeglasses
- Prescription spectacles, with side shields and protective lenses meeting requirements of ANSI Z87.1
- Goggles that can fit comfortably over corrective eyeglasses without disturbing their
alignment
- Goggles that incorporate corrective lenses mounted behind protective lenses

Face Shields
- Do not protect employees from impact hazards
- Use face shields in combination with goggles or safety spectacles when you must protect your employees from impact hazards, even in the absence of dust or potential splashes

Figure 1. Recommended Eye and Face Protectors
Source: 29 CFR 1926.102 (a)(5) Table E-1

Eye and face protectors are identified below by number and type. Refer to Table 1 for recommended usage applications.

1. GOGGLES, Flexible Fitting, Regular Ventilation
2. GOGGLES, Flexible Fitting, Hooded Ventilation
3. GOGGLES, Cushioned Fitting, Rigid Body
4. SPECTACLES, Metal Frame, With Sideshields*
5. SPECTACLES, Plastic Frame, With Sideshields*
6. SPECTACLES, Metal-Plastic Frame, With Flat-Fold Side shields*
7. WELDING GOGGLES, Eyecup type, Tinted Lenses**
7A. CHIPPING GOGGLES, Eyecup Type, Clear Safety Lenses (not illustrated)
8. WELDING GOGGLES, Eyecup type, Tinted Plate Lens**
8A. CHIPPING GOGGLES, Coverspec Type, Clear Safety Lenses (not illustrated)
9. WELDING GOGGLES, Coverspec Type, Tinted Plate Lens**
10. FACE SHIELD (Available With Plastic or Mesh Window, Tinted/Transparent)
11. WELDING HELMETS**

*These are also available without side shields for limited use requiring only frontal protection.
** See Table 2, Filter Lens Shade Numbers for Protection Against Radiant Energy.
Table 1. Eye and Face Protector Selection Guide  
Source: 29 CFR 1926.102(a)(5)

<table>
<thead>
<tr>
<th>Operation</th>
<th>Hazards</th>
<th>Recommended protectors: (see Figure 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylene-burning,</td>
<td>Sparks, harmful rays,</td>
<td>7,8,9</td>
</tr>
<tr>
<td>Acetylene-cutting,</td>
<td>molten metal, flying</td>
<td></td>
</tr>
<tr>
<td>Acetylenewelding</td>
<td>particles</td>
<td></td>
</tr>
<tr>
<td>Chemical handling</td>
<td>Splash, acid burns, fumes</td>
<td>2,10 (for severe exposure add 10 over 2)</td>
</tr>
<tr>
<td>Chipping</td>
<td>Flying particles</td>
<td>1,3,4,5,6,7A,8A</td>
</tr>
<tr>
<td>Electric (arc) welding</td>
<td>Sparks, intense rays,</td>
<td>9,11 (11 in combination with 4,5,6 in</td>
</tr>
<tr>
<td>Furnace operations</td>
<td>molten metal</td>
<td>tinted lenses advisable)</td>
</tr>
<tr>
<td>Grinding – light</td>
<td>Glare, heat, molten metal</td>
<td>7,8,9 (for severe exposure add 10)</td>
</tr>
<tr>
<td>Grinding – heavy</td>
<td>Flying particles</td>
<td>1,3,4,5,6,10</td>
</tr>
<tr>
<td>Laboratory</td>
<td>Chemical splash, glass</td>
<td>2 (10 when in breakage combination with</td>
</tr>
<tr>
<td>Machining</td>
<td>Flying particles</td>
<td>4,5,6)</td>
</tr>
<tr>
<td>Molten metals</td>
<td>Heat, glare, sparks, splash</td>
<td>7,8 (10 in combination with 4,5,6 in</td>
</tr>
<tr>
<td>Spot welding</td>
<td>Flying particles, sparks</td>
<td>tinted lenses)</td>
</tr>
</tbody>
</table>

How dark do lenses on welding helmets and goggles need to be?

The intensity of light or radiant energy produced by welding, cutting, or brazing operations varies according to a number of factors including the task producing the light, the electrode size, and the arc current. Table 2, Filter Lens Shade Numbers for Protection Against Radiant Energy, shows the minimum protective shade for a variety of welding, cutting, and brazing operations. To protect employees who are exposed to intense radiant energy, begin by selecting a shade too dark to see the welding zone. Then try lighter shades until you find one that allows a sufficient view of the welding zone without going below the minimum protective shade.
Table 2. Filter Lens Shade Numbers For Protection Against Radiant Energy
Source: 29 CFR 1926.102(b)(1)

<table>
<thead>
<tr>
<th>Welding operation</th>
<th>Shade Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shielded metal-arc welding 1/18, 3/32, 1/8, 5/32-inch diameter electrodes</td>
<td>10</td>
</tr>
<tr>
<td>Gas-shielded arc welding (nonferrous) 1/16, 3/32, 1/8, 5/32-inch diameter electrodes</td>
<td>11</td>
</tr>
<tr>
<td>Gas-shielded arc welding (ferrous) 1/16, 3/32, 1/8, 5/32-inch diameter electrodes</td>
<td>12</td>
</tr>
<tr>
<td>Shielded metal-arc welding 3/16, 7/32, 1/4-inch diameter electrodes</td>
<td>12</td>
</tr>
<tr>
<td>5/16, 3/8-inch diameter electrodes</td>
<td>12</td>
</tr>
<tr>
<td>Atomic hydrogen welding</td>
<td>10-14</td>
</tr>
<tr>
<td>Carbon-arc welding</td>
<td>14</td>
</tr>
<tr>
<td>Soldering</td>
<td>2</td>
</tr>
<tr>
<td>Torch brazing</td>
<td>3 or 4</td>
</tr>
<tr>
<td>Light cutting, up to 1 inch</td>
<td>3 or 4</td>
</tr>
<tr>
<td>Medium cutting, 1 inch to 6 inches</td>
<td>4 or 5</td>
</tr>
<tr>
<td>Heavy cutting, over 6 inches</td>
<td>5 or 6</td>
</tr>
<tr>
<td>Gas welding (light), up to 1/8 inch</td>
<td>4 or 5</td>
</tr>
<tr>
<td>Gas welding (medium), 1/8 inch to ½ inch</td>
<td>5 or 6</td>
</tr>
<tr>
<td>Gas welding (heavy), over ½ inch</td>
<td>6 or 8</td>
</tr>
</tbody>
</table>

Materials:

Assorted hearing protection
Assorted safety glasses and shields
Safety shoe sectional
Assorted hand gloves

Procedure:

**Practical Exercise #1**: Examine the supplied materials, and use the background information provided in the preceding pages and your reading of the textbook to identify the following.

List three types of eye protection:
1. 
2. 
3. 

List three types of foot protection:
1. 
2. 
3. 

List two types of head protection:
1. 
2. 

List three types of protective clothing:
1. 
2. 
3. 

List three types of gloves:
1. 
2. 
3.
List three types of hearing protection and give the Noise Reduction Rating (NRR) for each:

1. 
2. 
3. 

**Practical Exercise #2: (Optional)** Using Appendix A of the *Guidelines for Selection of Protective Clothing by the ACGIH*, find the following information.

1. For the following chemicals, give the “best” resistant material that has the longest breakthrough time in hours:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Resistant Material</th>
<th>Breakthrough Time (Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethyl Alcohol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Give the permeation rate for the following materials of each chemical listed below:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Material</th>
<th>Breakthrough Time (Hrs)</th>
<th>Permeation rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl Ethyl Ketone</td>
<td>Nitrile</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Methyl Ethyl Ketone</td>
<td>Neoprene</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>Neoprene</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Neoprene-Natural Rubber</td>
<td>1.53</td>
<td></td>
</tr>
</tbody>
</table>

**Define:** *(Use Guidelines for Selection of Protective Clothing)*

Permeation Rate:

Breakthrough Time:

List five factors that influence permeation rate and breakthrough time, and provide a short description of each one:

1. 
2. 
3. 
4. 
5. 
**Practical Exercise #3:** Using the OSHA website, complete the following exercise.

For the following codes, find the corresponding body part and write the first non-italicized sentence of the paragraph. The first line is completed as an example.

<table>
<thead>
<tr>
<th>Code</th>
<th>Body Part</th>
<th>Sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 CFR 1910.252 (b)</td>
<td>Eyes</td>
<td>Eye protection in the form of suitable goggles shall be provided where needed for brazing operations not covered in paragraphs (b)(2)(i)(A) through (b)(2)(i)(C) of this section.</td>
</tr>
<tr>
<td>29 CFR 1910.132(a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 CFR 1910.133(a)(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 CFR 1910.134(a)(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 CFR 1910.135(a)(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 CFR 1910.136(a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 CFR 1910.95 (i) (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 CFR 1910.156 (e)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Practical Exercise #4: (Refer to chapter 23 for additional information) Answer the following questions.

1. What does PPE stand for?

2. List 5 areas PPE should protect:
   1. 
   2. 
   3. 
   4. 
   5. 

3. Describe how you might persuade workers to wear PPE.

4. List some hazards of wearing PPE.

5. True or false: PPE should be used in conjunction with other protective methods?

6. What is the safety zone inside hard hats?

7. Where and why should one wear safety shoes?

8. What is the impact stress test on the toe of a steel tip boot?

9. What are the OSHA impact requirements for eye protection lenses?

10. What symbol will be found on eye protection that meets OSHA standards?
Laboratory #2
Calibration of Air Flows
Laboratory #2—Calibration of Air Flows

Background:

Proper calibration of air flow is extremely important for eliminating bias in the collection and measurement of air pollutants. Air flow calibration devices can be broken down into primary and secondary standards. Primary devices provide a direct measurement of air flow. Secondary devices provide an indirect measure and must be periodically calibrated with a primary calibration device. Refer to *FIH* 6e, Chapter 16, pages 539–541, for additional details.

A linear regression produces the slope of a line that best fits a single set of data. Regression lines can be used as a way of visually depicting the relationship between the independent (x) and dependent (y) variables in the graph. In addition to visually depicting the trend in the data with a regression line, you can also calculate the equation of the regression line. The standard format of a linear regression equation is: \( y = mx + b \), where \( m \) is the slope of the line and \( b \) is the zero intercept. This equation can be used to predict the value of a variable based on the value of the other variable.

How well this equation describes the data (the “goodness of fit”), is expressed as a correlation coefficient, \( R^2 \) (R-squared). The closer \( R^2 \) is to 1.00, the better the fit. Linear regressions are commonly used to provide a correction to the value of secondary standards as compared to a primary standard. For use as a calibration equation, the \( R^2 \) value is expected to be 0.95 or greater. (See the tutorial note after Practical Exercise #3.)

Materials:

- 37 mm cassette
- Backup pad
- Membrane filter
- Bubble meter
- Rotameter
- Tubing
- Quick connects
- Buck calibrator
- Accuflow calibrator
- Soup solution
- Air sampling pump

Procedure:

**Practical Exercise #1:** Calibration of a rotameter with a bubble meter

1. Goal: Measure room temperature and barometric pressure.
   - Temperature: _________
   - Pressure: ___________

2. Arrange apparatus as shown in Figure 1 (on the next page) without the filter cassette.
Figure 1

Note: Solid lines indicate initial setup.
Dotted lines note position of insert for parts 4 and 5
3. Calibrate the rotameter with the ball at each of the following settings—2, 3, and 4 lpm. Take readings at the center of the ball. To calibrate, take three soap bubble meter readings at each rotameter reading. Use a stopwatch to time the transit for a predetermined volume.

<table>
<thead>
<tr>
<th>Rotameter (lpm)</th>
<th>Volume (ml)</th>
<th>Time (sec)</th>
<th>Liters/minute (lpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>4</td>
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<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Place the cassette in position 1 and set the rotameter to 3.0 LPM. Check the flow three times with the bubble meter.

<table>
<thead>
<tr>
<th>Rotameter (lpm)</th>
<th>Volume (ml)</th>
<th>Time (sec)</th>
<th>Liters/minute (lpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Now place the cassette in position 2 and set the rotameter to 3.0 LPM. Check the flow three times with the bubble meter.

<table>
<thead>
<tr>
<th>Rotameter (lpm)</th>
<th>Volume (ml)</th>
<th>Time (sec)</th>
<th>Liters/minute (lpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
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<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALCULATIONS:

1. Convert milliliter to liters: 1000 ml = 1 L
2. Convert seconds to minutes: 60 seconds = 1 minute
3. Calculate the flow rate at each point.

\[ Q = \frac{V}{t} \]

Where \( Q \) = flow rate in liters per minute
\( V \) = volume in liters
\( t \) = time in minutes

1. Plot the rotameter readings (Y) from Step 3 versus the calculated flow rates (X) on a linear graph. Determine a least squares fit of the data (linear regression). Where flow rate is the X variable and rotameter reading is the Y variable.

2. Determine the mean flow rates of the rotameter with the filter in position 1 and position 2.
**Practical Exercise #2:** Calibration of a rotameter with an electronic meter

1. Arrange the apparatus as shown in Figure 2.1, substituting the electronic meter for the bubble meter. Do not include the filter cassette.

2. Calibrate the rotameter with the ball at settings of 1, 1.6, 2, 2.4, and 3 lpm. Take readings at the center of the ball. To calibrate, take three electronic meter readings at each rotameter reading.

<table>
<thead>
<tr>
<th>Rotameter (lpm)</th>
<th>Flow Rate (lpm)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td></td>
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<tr>
<td>2.0</td>
<td></td>
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<tr>
<td>2.0</td>
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<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td></td>
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<tr>
<td>2.4</td>
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<tr>
<td>2.4</td>
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<td></td>
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<tr>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Place the cassette in position 1 and set the rotameter to 2. Check the flow three times with the bubble meter.

<table>
<thead>
<tr>
<th>Rotameter (lpm)</th>
<th>Flow Rate (lpm)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Now place the cassette in position 2 and set the rotameter to 2. Check the flow three times with the bubble meter.

<table>
<thead>
<tr>
<th>Rotameter (lpm)</th>
<th>Flow Rate (lpm)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATIONS:**

1. Calculate the average flow rate at each point.

2. Plot the rotameter readings (Y) from Step 2 versus the calculated flow rates (X) on a linear graph. Determine a least squares fit of the data (linear regression). Where: Flow Rate is the X variable and rotameter reading is the Y variable.

3. Determine the mean flow rates of the rotameter with the filter in position 1 and position 2.
Practical Exercise #3: Questions

For Discussion:
The following questions are to assist with the write-up in the Discussion Section. Your discussion should be in paragraph form. The questions are intended to provide you with a starting point for your discussion, and you will need to expand beyond the question. Do not just write as question and answer.

1. How did the filter affect the calibration of the rotameter? How did the measured rates compare to the rate predicted by the regression?

2. How did the regression for the bubble meter compare to the regression for the electronic meter?

Answer the following questions:

1. Time measurement is one of the critical parameters in calibrating flow rate and volume. Would a stopwatch be considered a primary standard? How could you verify/calibrate the stopwatch?

2. Where should you place the rotameter in the sampling train (pump, rotameter, sample); to get an accurate reading? Why?

3. Why might flow measurements be highly variable? How would you correct this?

4. Which of the flow measurement devices are primary standards, and which are secondary standards?

Note: Regression can be conducted in Microsoft Excel.
Laboratory #3
Respirators
Laboratory #3—Respirators

Background:

Respiratory Protective Devices vary in design, equipment specifications, application, and protective capability. Proper selection depends on the toxic substance involved, conditions of exposure, human capabilities, and equipment fit. If, after effective engineering controls have been fully used in reducing exposure to the lowest possible level, the environment is still not completely safe, it will be necessary to protect the worker from contact with airborne contaminants or oxygen-deficient environments. The purpose of this project is to provide detailed discussion of the use, maintenance, and limitations of respiratory protection and its protective clothing. The laboratory exercises were created to enable the student to do the following: identify the need for effective respiratory protection, understand the operating principles of selected respirators, recognize the use and limitation of respirator types, understand the importance of properly fitting the respirator, and become familiarized with the concept of protection factors and how they relate to respirator selection and use.

Materials:

- Respirator inventory
- Quantitative respirator fit tester, DNI Nevada
- Half-Mask respirator
- Appropriate test adaptors
- Alcohol pads
- Paper and pencil

Procedure:

Practical Exercise #1: Inspecting respiratory protective devices for damage and deterioration

Use the information provided on page 654 of FIH 6e to conduct your inspection.

A. Inspect each of the specified respirators for signs of damage or deterioration, including missing or damaged parts, cracks, tears, loss of flexibility, modifications, etc., and record your observations. Include the manufacturer, model name, and respirator type; faults observed; and corrective measures required.

B. Identify corrective measures required to make the respirator useable, if any.
<table>
<thead>
<tr>
<th>#</th>
<th>Manufacture and model</th>
<th>Type</th>
<th>Faults</th>
<th>Corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<td>3</td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>7</td>
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<td>8</td>
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<td>9</td>
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</tr>
<tr>
<td>10</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Practical Exercise #2: Selecting an appropriate respiratory protective device

A. For each exposure scenario specified by the instructor, identify the information items needed to choose an appropriate respiratory protective device.

B. Using the NIOSH decision logic provided on the next two pages, specify the type of respirator to be used for each of the following cases. If you select an air purifying respirator, make sure to indicate what type of cartridge would be used. Justify your respirator choice based on the NIOSH decision logic described on the next 12 pages.

Case 1 Wipe cleaning of small items in a large workshop using rags soaked in methyl ethyl ketone (MEK, 2-butane). Detector tube sampling suggests concentrations around 750 ppm.

Respirator Selected: 

Justification: 

Case 2 Grinding painted surfaces containing potentially toxic pigments (but no lead). Airborne pigment concentration is approximately 15 times the PEL for the most toxic component.

Respirator Selected: 

Justification: 

Case 3 Cleaning sludge off the bottom of a tank normally used to store waste solvent. No sampling data is available.

Respirator Selected: 

Justification: 

Case 4 Sanding new pine furniture prior to finishing. There is no PEL for pine dust, but concentrations are measured at approximately 5 mg/m³ as inhalable dust, of which 2 mg/m³ is of respirable size.

Respirator Selected: 

Justification:
III. Respirator Selection Logic Sequence

After all criteria have been identified and evaluated and after the requirements and restrictions of the respiratory protection program have been met, the following sequence of questions can be used to identify the class of respirators that should provide adequate respiratory protection. Note that if OSHA has promulgated a substance – specific standard for a contaminant found in your workplace, respirator selection must meet or exceed the respirators required in that standard. (OSHA General Industry Air Contaminants Standard, 29 CFR 1910.1000).

Step 1. Is the respirator intended for use during fire fighting?


b. If no, proceed to Step 2.

Step 2. Is the respirator intended for use in an oxygen-deficient atmosphere, i.e., less than 19.5% oxygen?

a. If yes, any type of SCBA other than escape only, or supplied-air respirator (SAR) with an auxiliary SCBA is required. Auxiliary SCBA must be of sufficient duration to permit escape to safety if the air supply is interrupted.

If yes, and contaminants are also present, proceed to Step 3 to determine if the hazard requires the SCBA or SAR/SCBA to meet a specific APF level.

b. If no, proceed to Step 3.

Step 3. Is the respirator intended for entry into unknown or IDLH atmospheres (e.g., an emergency situation)?

a. If yes, one of two types of respirators are required: a pressure-demand SCBA with a full facepiece or a pressure-demand SAR with a full facepiece in combination with an auxiliary pressure-demand SCBA. Auxiliary SCBA must be of sufficient duration to permit escape to safety if the air supply is interrupted.

b. If no, proceed to Step 4.

Step 4. Is the exposure concentration of the contaminants, as determined by acceptable industrial hygiene methods, less than the NIOSH REL or other applicable exposure limit?

a. If yes, a respirator is not required for routine work. For escape respirators, determine the potential for generation of a hazardous condition caused by an accident, spill or equipment failure. See Section IV. Page 17, for a discussion and selection of escape respirators. Proceed to Step 6.*

b. If no, proceed to Step 5.

* If respirators are required by the employer to be worn (even if below the occupational exposure limit), OSHA requires that the employer establish and implement a written respiratory protection program with worksite specific procedures. If an employer provides respirators at the request of employees or permits employees to use their own respirators when exposure levels are below the applicable limits, this is considered voluntary respirator use. OSHA requires that employers provide to their employees the information contained in Appendix D of 29 CFR 1910.134, that they establish and implement those elements of a written program necessary to ensure that any employee using a respirator voluntarily is medically able to wear the respirator (except that medical evaluation is not required for voluntary use of filtering facepieces) and that the respirator is cleaned, stored, and maintained so that it does not represent a health hazard to the wearer.

Step 5. Are conditions such that a worker who is required to wear a respirator can escape from the work area and not suffer loss of life or immediate or delayed irreversible health effects if the respirator fails, i.e., are the conditions not immediately dangerous to life or health (IDLH)? IDLH values for certain compounds can be found in the NIOSH Pocket Guide for Chemical Hazards. This document can be accessed at [http://www.cdc.gov/niosh/npg/npg.html](http://www.cdc.gov/niosh/npg/npg.html). IDLH values for some substances can also be found on the NIOSH internet at [http://www.cdc.gov/niosh/idlh/idlh-1.html](http://www.cdc.gov/niosh/idlh/idlh-1.html).

a. If yes, conditions are not considered to be IDLH. Proceed to Step 6.

b. If no, conditions are considered to be IDLH. Two types of respirators are recommended: a pressure-demand, full-facepiece SCBA or a pressure-demand, full-facepiece SAR in combination with an auxiliary pressure-demand, full-facepiece SCBA. The auxiliary SCBA must be of sufficient duration to permit escape to safety if the air supply is interrupted. An auxiliary unit means that the SAR unit includes a separate air bottle to provide a reserve source of air should the airline become damaged. The auxiliary unit shares the same mask and regulator, and enables the SAR to function as an SCBA if needed.

Step 6. Is the contaminant an eye irritant, or can the contaminant cause eye damage at the workplace concentration? Information on eye irritation is included

a. If yes, a respirator equipped with a full facepiece, helmet, or hood is recommended. Proceed to Step 7.

b. If no, a half-mask or quarter-mask respirator may still be an option, depending on the exposure concentration. Proceed to Step 7.

Step 7. Determine the maximum hazard ratio (HR) by the following:

- Divide the time-weighted average (TWA) exposure concentration for the contaminant determined in Step 4 by the NIOSH REL or other applicable exposure limit. If the exposure limit is an 8 hour limit the TWA used must be on 8 hour average. If the exposure limit is based on 10 hours, use a 10 hour TWA.

- If the contaminant has a ceiling limit, divide the maximum exposure concentration for the contaminant determined in Step 4 by the ceiling limit.

- If the contaminant has a short term exposure limit (STEL), divide the maximum 15 min TWA exposure concentration for the contaminant determined in Step 4 by the STEL.

- For escape respirators, determine the potential for generation of a hazardous condition caused by an accident or equipment failure.

- If a potentially hazardous condition could occur or a hazard ratio greater than 1 has been calculated, proceed to Step 8.

Step 8. If the physical state of the contaminant is:

- a particulate (solid or liquid aerosol) during periods of respirator use, proceed to Step 9;

- a gas or vapor, proceed to Step 10;

- a combination of gas or vapor and particulate, proceed to Step 11.

Step 9. Particulate Respirators

9.1. Is the particulate respirator intended only for escape purposes?
a. If yes, see Section IV (page 17), for a discussion and selection of escape respirators.

b. If no, the particulate respirator is intended for use during normal work activities. Proceed to Step 9.2.

9.2. A filter series (N, R or P) that will provide protection against exposure to the particulate in question is recommended.

a. The selection of N-, R-, and P-series filters depends on the presence or absence of oil particles, as follows:

- If no oil particles are present in the work environment, use a filter of any series (i.e., N-, R-, or P-series).

- If oil particles (e.g., lubricants, cutting fluids, glycerine, etc.) are present, use an R- or P-series filter. Note: N-series filters cannot be used if oil particles are present.

- If oil particles are present and the filter is to be used for more than one work shift, use only a P-series filter.

\[\text{Note: To help you remember the filter series, use the following guide:} \]
\[\text{N for Not resistant to oil,} \]
\[\text{R for Resistant to oil,} \]
\[\text{P for oil Proof} \]

b. Selection of filter efficiency (i.e., 95%, 99%, or 99.97%) depends on how much filter leakage can be accepted. Higher filter efficiency means lower filter leakage.

Additional information on selecting the appropriate filter certified under 42CFR84 can be found at http://www.cdc.gov/NIOSH/userguid.html. Proceed to Step 9.3.

9.3. Respirators that have not been eliminated from Table 1 by the previous steps and that have APFs equal to, or greater than, the maximum hazard ratio determined in Step 7 are recommended. Note, however, that the maximum use concentration (MUC) is the maximum atmospheric concentration of a hazardous substance from which an employee can be expected to be protected by a class of respirator and is determined by the lesser of:

- APF X exposure limit
- The respirator manufacturer’s MUC for a hazardous substance (if any)

\[\text{Note: If the respirator is intended for use in an oxygen-deficient atmosphere, only SCBA or SAR with an auxiliary SCBA, can be selected from the Table.} \]
• The IDLH, unless the respirator is a pressure-demand, full-facepiece SCBA or combination pressure-demand SAR with a full facepiece in combination with an auxiliary pressure-demand SCBA.

For multi-component mixtures the MUC can be calculated by:
\[ \frac{C_1}{MUC_1} + \frac{C_2}{MUC_2} + \ldots + \frac{C_n}{MUC_n} = 1 \]

Step 10. Gas/Vapor Respirators

10.1. Is the gas/vapor respirator intended only for escape?

a. If yes, refer to escape respirators Section IV (page 17).

b. If no, the gas/vapor respirator is intended for use during normal work activities. Proceed to Step 10.2.

10.2. An air-purifying chemical cartridge/canister respirator is recommended that has a sorbent suitable for the chemical properties of the anticipated gas/vapor contaminant(s) and for the anticipated exposure levels. Information on cartridges or canisters approved for use for classes of chemicals or for specific gases or vapors can be found in the NIOSH Certified Equipment List http://www.cdc.gov/NIOSH/npptl/topics/respirators/cell/. Proceed to Step 10.3.

10.3. Respirators that have not been eliminated from Table 3 by the previous steps and that have APFs equal to, or greater than, the maximum hazard ratio determined in Step 7 are recommended.\(^1\) Note, however, that the maximum use concentration (MUC) is the maximum atmospheric concentration of a hazardous substance from which an employee can be expected to be protected by a class of respirator and is determined by the lesser of:

• APF X exposure limit
• The respirator manufacturer’s MUC for a hazardous substance (if any)
• The IDLH, unless the respirator is a pressure-demand, full-facepiece SCBA or combination pressure-demand SAR with a full facepiece in combination with an auxiliary pressure-demand SCBA.

For multi-component mixtures the MUC can be calculated by:
\[ \frac{C_1}{MUC_1} + \frac{C_2}{MUC_2} + \ldots + \frac{C_n}{MUC_n} = 1 \]

\(^1\) If the respirator is intended for use in an oxygen-deficient atmosphere, only SCBA or SAR with an auxiliary SCBA, can be selected from the Table.
Step 11. Combination Particulate and Gas/Vapor Respirators

11.1. Is the combination respirator intended for "escape only" purposes?

a. If yes, refer to escape respirators on page 17, for a discussion and selection of "escape only" respirators.

b. If no, the combination respirator is intended for use during normal work activities. Proceed to Step 11.2.

11.2 From Table 3, select a respirator type, not eliminated by the previous steps, and have APFs equal to, or greater than, the maximum hazard ratio determined in Step 7. are recommended.\textsuperscript{1} Note, however, that the maximum use concentration (MUC) is the maximum atmospheric concentration of a hazardous substance from which an employee can be expected to be protected by a class of respirator and is determined by the lesser of:

- APF X exposure limit
- The respirator manufacturer’s MUC for a hazardous substance (if any)
- The IDLH, unless the respirator is a pressure-demand, full-facepiece SCBA or combination pressure-demand SAR with a full facepiece in combination with an auxiliary pressure-demand SCBA.

For multi-component mixtures the MUC can be calculated by:
\[\frac{C_1}{\text{MUC}_1} + \frac{C_2}{\text{MUC}_2} + \ldots + \frac{C_n}{\text{MUC}_n} = 1\]

\textsuperscript{1}If the respirator is intended for use in an oxygen-deficient atmosphere, only SCBA or SAR with an auxiliary SCBA, can be selected from the Table.
<table>
<thead>
<tr>
<th>Assigned protection(^1) factor</th>
<th>Type of Respirator</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Quarter mask respirator</td>
</tr>
</tbody>
</table>
| 10                               | Any air-purifying elastomeric half-mask respirator equipped with appropriate type of particulate filter.\(^2\)  
Appropriate filtering facepiece respirator.\(^2,3\)  
Any air-purifying full facepiece respirator equipped with appropriate type of particulate filter.\(^2\)  
Any negative pressure (demand) supplied-air respirator equipped with a half-mask. |
| 25                               | Any powered air-purifying respirator equipped with a hood or helmet and a high efficiency (HEPA) filter.  
Any continuous flow supplied-air respirator equipped with a hood or helmet. |
| 50                               | Any air-purifying full facepiece respirator equipped with N-100, R-100, or P-100 filter(s).  
Any powered air-purifying respirator equipped with a tight-fitting facepiece (half or full facepiece) and a high-efficiency filter.  
Any negative pressure (demand) supplied-air respirator equipped with a full facepiece.  
Any continuous flow supplied-air respirator equipped with a tight-fitting facepiece (half or full facepiece).  
Any negative pressure (demand) self-contained respirator equipped with a full facepiece. |

\(^1\) The protection offered by a given respirator is contingent upon (1) the respirator user adhering to complete program requirements (such as the ones required by OSHA in 29CFR1910.134), (2) the use of NIOSH-certified respirators in their approved configuration, and (3) individual fit testing to rule out those respirators that cannot achieve a good fit on individual workers.

\(^2\) Appropriate means that the filter medium will provide protection against the particulate in question. See step 9.2 for information on the presence or absence of oil particulates.

\(^3\) An APF of 10 can only be achieved if the respirator is qualitatively or quantitatively fit tested on individual workers.
Table 1. Particulate Respirators

<table>
<thead>
<tr>
<th>Assigned protection(^1) factor</th>
<th>Type of respirator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>Any pressure-demand supplied-air respirator equipped with a half-mask.</td>
</tr>
<tr>
<td>2,000</td>
<td>Any pressure-demand supplied-air respirator equipped with a full facepiece.</td>
</tr>
</tbody>
</table>
| 10,000                           | Any pressure-demand self-contained respirator equipped with a full facepiece.  
Any pressure-demand supplied-air respirator equipped with a full facepiece in combination with an auxiliary pressure-demand self-contained breathing apparatus. |

\(^1\) The protection offered by a given respirator is contingent upon (1) the respirator user adhering to complete program requirements (such as the ones required by OSHA in 29CFR1910.134), (2) the use of NIOSH-certified respirators in their approved configuration, and (3) individual fit testing to rule out those respirators that cannot achieve a good fit on individual workers.
### Table 2. Gas/Vapor Respirators

<table>
<thead>
<tr>
<th>Assigned protection factor&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Type of respirator</th>
</tr>
</thead>
</table>
| 10                                   | Any air-purifying half mask respirator equipped with appropriate gas/vapor cartridges.<sup>2</sup>  
Any negative pressure (demand) supplied-air respirator equipped with a half mask. |
| 25                                   | Any powered air-purifying respirator with a loose-fitting hood or helmet equipped with appropriate gas/vapor cartridges.<sup>2</sup>  
Any continuous flow supplied-air respirator equipped with a hood or helmet. |
| 50                                   | Any air-purifying full facepiece respirator equipped with appropriate gas/vapor cartridges<sup>2</sup> or gas mask (canister respirator).<sup>2</sup>  
Any powered air-purifying respirator equipped with a tight-fitting facepiece (half or full facepiece) and appropriate gas/vapor cartridges or canisters.<sup>2</sup>  
Any negative pressure (demand) supplied-air respirator equipped with a full facepiece.  
Any continuous flow supplied-air respirator equipped with a tight-fitting facepiece (half or full facepiece).  
Any negative pressure (demand) self-contained respirator equipped with a full facepiece. |
| 1,000                                | Any pressure-demand supplied-air respirator equipped with a half-mask.               |

1 The protection offered by a given respirator is contingent upon (1) the respirator user adhering to complete program requirements (such as the ones required by OSHA in 29CFR1910.134), (2) the use of NIOSH-certified respirators in their approved configuration, and (3) individual fit testing to rule out those respirators that cannot achieve a good fit on individual workers.

2 Select a cartridge/canister certified to be used for the specific class of chemicals or the specific gas/vapor found in your workplace.
<table>
<thead>
<tr>
<th>Assigned protection factor(^1)</th>
<th>Type of respirator</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000</td>
<td>Any pressure-demand supplied-air respirator equipped with a full facepiece.</td>
</tr>
<tr>
<td>10,000</td>
<td>Any pressure-demand self-contained respirator equipped with a full facepiece.</td>
</tr>
<tr>
<td></td>
<td>Any pressure-demand supplied-air respirator equipped with a full facepiece in combination with an auxiliary pressure-demand self-contained breathing apparatus.</td>
</tr>
</tbody>
</table>

\(^1\) The protection offered by a given respirator is contingent upon (1) the respirator user adhering to complete program requirements (such as the ones required by OSHA in 29CFR1910.134), (2) the use of NIOSH-certified respirators in their approved configuration, and (3) individual fit testing to rule out those respirators that cannot achieve a good fit on individual workers.
### Table 3. Combination Gas/Vapor & Particulate Respirators

<table>
<thead>
<tr>
<th>Assigned protection factor(^1)</th>
<th>Type of respirator</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Any air-purifying half-mask respirator equipped with appropriate gas/vapor cartridges(^2) in combination with appropriate type of particulate filter.(^3)</td>
</tr>
<tr>
<td></td>
<td>Any full facepiece respirator with appropriate gas/vapor cartridges(^2) in combination with appropriate type of particulate filter.(^3)</td>
</tr>
<tr>
<td></td>
<td>Any negative pressure (demand) supplied-air respirator equipped with a half-mask.</td>
</tr>
<tr>
<td>25</td>
<td>Any powered air-purifying respirator with a loose-fitting hood or helmet that is equipped with an appropriate gas/vapor cartridge(^2) in combination with a high-efficiency particulate filter.</td>
</tr>
<tr>
<td></td>
<td>Any continuous flow supplied-air respirator equipped with a hood or helmet.</td>
</tr>
<tr>
<td>50</td>
<td>Any air-purifying full facepiece respirator equipped with appropriate gas/vapor cartridges(^2) in combination with an N-100, R-100 or P-100 filter or an appropriate canister(^2) incorporating an N-100, P-100 or R-100 filter.</td>
</tr>
<tr>
<td></td>
<td>Any powered air-purifying respirator with a tight-fitting facepiece (half or full facepiece) equipped with appropriate gas/vapor cartridges(^2) in combination with a high-efficiency filter or an appropriate canister(^2) incorporating a high-efficiency filter.</td>
</tr>
<tr>
<td></td>
<td>Any negative pressure (demand) supplied-air respirator equipped with a full facepiece.</td>
</tr>
<tr>
<td></td>
<td>Any continuous flow supplied-air respirator equipped with a tight-fitting facepiece (half or full facepiece).</td>
</tr>
<tr>
<td></td>
<td>Any negative pressure (demand) self-contained respirator equipped with a full facepiece.</td>
</tr>
</tbody>
</table>

1 The protection offered by a given respirator is contingent upon (1) the respirator user adhering to complete program requirements (such as the ones required by OSHA in 29CFR1910.134), (2) the use of NIOSH-certified respirators in their approved configuration, and (3) individual fit testing to rule out those respirators that cannot achieve a good fit on individual workers.

2 Select a cartridge/canister certified to be used for the specific class of chemicals or the specific gas/vapor found in your workplace.

3 Appropriate means that the filter medium will provide protection against the particulate in question. See step 9.2 for information on the presence or absence of oil particulates.
**Table 3. Combination Gas/Vapor and Particulate Respirators**

**Continued**

<table>
<thead>
<tr>
<th>Assigned protection factor</th>
<th>Type of respirator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>Any pressure-demand supplied-air respirator equipped with a half-mask.</td>
</tr>
<tr>
<td>2,000</td>
<td>Any pressure-demand supplied-air respirator equipped with a full facepiece.</td>
</tr>
<tr>
<td>10,000</td>
<td>Any pressure-demand self-contained respirator equipped with a full facepiece.</td>
</tr>
<tr>
<td></td>
<td>Any pressure-demand supplied-air respirator equipped with a full facepiece in</td>
</tr>
<tr>
<td></td>
<td>combination with an auxiliary pressure-demand self-contained breathing apparatus.</td>
</tr>
</tbody>
</table>

1 The protection offered by a given respirator is contingent upon (1) the respirator user adhering to complete program requirements (such as the ones required by OSHA in 29CFR1910.134), (2) the use of NIOSH-certified respirators in their approved configuration, and (3) individual fit testing to rule out those respirators that cannot achieve a good fit on individual workers.
**Practical Exercise #3a:** Performing a quantitative fit test on two team members  
**#3b:** Performing a qualitative fit test on one team member  

**Class Guidelines for Conducting the Quantitative Fit Test Activity**

1. Locate Quantitative Fit Tester, test adapters, and half-mask respirator.

2. Each person in the group will complete the pre-test; then choose one person from the group to complete Protocol 1.

3. If a person does not pass the pre-test, that person should not be chosen to complete the protocol.

4. Follow all safety rules while performing tests.

**3a. The Quantitative Fit Test Procedure:**

Prior to starting the exercise review the operation manual for the quantitative fit tester to be used. Follow all safety rules while performing tests. Be sure to clean mask thoroughly between uses and users. Based on the instructions in the manual complete the following activities

A. Locate Quantitative Fit Tester, test adapters and a half-mask or full face respirator.  
B. Each person in the group will complete a positive and negative pressure check on the selected mask as detailed below.
   i. Positive pressure check:
      a. Don the mask and adjust the straps until mask feels snug. Caution: Do not over tighten straps.  
      b. Place heel of the palm over the exhalation valve, sealing the opening.  
      c. Breath out slowly. Gently inflating mask and feel for leaks around the face seal of the mask. Caution: Forceful exhalation will lift the mask from the face regardless of fit.  
      d. If leaks are felt adjust the straps of the mask and repeat.  
      e. If leaks persist stop and switch user if there are no leaks leave mask on and proceed to negative pressure check.  
   ii. Negative pressure check
      a. With mask on, place the heels of the palms over the filter cassettes or inhalation valves, sealing the opening.  
      b. Inhale gently creating a negative pressure inside the mask and feel for leaks.  
      c. If leaks are felt adjust the straps of the mask and repeat.  
      d. If leaks persist stop and switch users if there are no leaks leave mask on and proceed to fit test.

Note: If a person does not pass the pressure tests, that person should not be chosen to complete the fit test protocol.
C. Follow the manufactures instructions for OSHA test protocol for a quantitative fit test.

Question: Did your group have an individual complete the testing protocol? If so, what was the result? If not, at what stage did they fail and why? Make suggestions as to what could be changed so that the individual could pass the test protocol.
3b.  **Conducting the Qualitative Fit Test**

Locate the qualitative fit test equipment. Review the instructions provided with the equipment. Have one member of your group don a dust mask. **Wait at least 10 minutes before proceeding with the test.** Using the table below, note if the individual passed or failed the initial test. If the sensitivity solution was used, note how many puffs were necessary for the individual to respond to the solution.

<table>
<thead>
<tr>
<th>Solution</th>
<th># Puffs</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: If the individual failed, explain why and suggest an alternative approach.
Practical Exercise #4: Answer the corresponding questions concerning respirators.

1. What are two key requirements of a respiratory protection program?

2. What is the major objective in the selection process based upon?

3. What are the three types of atmosphere—supplying respirators?

4. What are the five inspection points on a respirator?

5. What must you do after you inspect your respirator?
Laboratory #4
Particulates
Laboratory #4—Particulates

Background:

In common usage, the term “aerosol” is taken to mean the droplet spray produced from an “aerosol can” containing a liquid and a compressed gas propellant. In industrial hygiene an aerosol is an assemblage of solid or liquid particles dispersed in a gaseous medium (air). Aerosol-producing activities include mining, welding, smelting, and crop processing. Aerosols may react with or be absorbed through tissues to cause adverse health effects. The health effects of particulate exposure depend on the size, shape, and density of the particles, the chemical properties, concentration, length of exposure, environmental factors, and other individual risk factors. In order to determine the appropriate control methods, particulate exposure must be characterized. No single sampling and analysis technique is appropriate to all needs, so it is important for the industrial hygienist to be familiar with the properties of aerosols in the occupational environment and the techniques available for their assessment.

Size-selective samplers are one group of analytic tools. A type of size-selective sampler is one designed to collect physiologically related size fractions. The three fractions commonly collected are those related to the upper, middle, and lower respiratory tract. These are called inhalable, thoracic, and respirable respectively.

Other commonly used samplers are the 25-mm, 37-mm, or 47-mm cassettes. Traditionally these types of samplers have been called “total dust” samplers; however, research has shown that these devices may significantly undersample. This undersampling effect is especially significant for larger particles.

The biological QuickTake™ 15 is a portable, battery-powered air sampling pump designed specifically to provide constant airflow for the short sampling times required for mold screening. It allows timed samples to be taken within the flow range of 5 to 15 L/min, maintains constant flow, and is suitable for use with Air-O-Cell Cassettes.
Materials:

Air sampling pump  Battery charger
Balance  Rotameter
Aluminum cyclone 37 mm  Forceps
Cartridge opener  Dust chamber
Vacuum pump  Cyclone calibration adaptor
Stopwatch  Microscope
Tripod  QuickTake™ 15
High-flow rotameter

Supplies:
Cartridges 37 mm  Filters 37 mm mixed cellulose ester
Tubing  Support pads
Biological sampling cassette  Glass slide
Lacto phenol cotton blue stain

Follow all safety rules while performing tests.

Read the instruction manual for each piece of equipment and become familiar with the Flow Sample Pump operation and the 5 Station Sampler Battery Pack charging station.

Note: Performance of this lab exercise will require overnight charging of pumps!

Practical Exercise #1: Particulate sampling and analysis

Procedure:

I. Use the Mettler balance to pre-weigh 37-mm MCE filters.

1. First, become familiar with procedures for zeroing, loading, reading, and unloading the Mettler balance.
2. Place a weighing paper on the balance pan.
3. Zero the balance with a weighing paper on the balance pan.

Note: Do not touch either the filter or the support pad with your fingers as this will result in inaccurate readings.

4. Carefully remove the top section and spacer ring of a 37-mm cassette. (See diagram from Chapter 16 below for cassette assembly.)
5. With the forceps, put a support pad in the bottom section of the cassette (the part with a waffle pattern).

6. Using forceps remove a Mixed Cellulose Esters filter from the filter box and place on the weighing paper.

7. Record initial filter weight in table below.

8. Gently grasp the filter with a forceps and transfer it to the bottom section of the cassette on top of the support pad.

9. Replace the spacer ring and top section and apply just enough pressure to seat the sections.

10. Mark cassette with a unique identifier.

11. Prepare a second cassette by repeating Steps 3 through 10.

II. Calibration of sampling pumps.

1. Select two air sampling pumps.

2. Note a unique identifier for each pump.

3. Using a rotameter and a dummy cassette (NOT your pre-weighed cassettes), calibrate one pump to \(2.0 \pm 0.3\) liters per minute (LPM).

4. Using a rotameter and a dummy cyclone sampler calibrate the second pump to exactly 2.1 liters per minute.

5. Record the flow rates in the table below.

   Note: The pump set at 2.1 LPM will be used to collect the cyclone sample. Do not mix up your cassettes.

---

*Figure 16–9. Standard filters are 37 mm in diameter and are placed in closed-face cassettes with a backup pad, which prevents contamination. (Reprinted with permission from OSHA Technical Manual)*
III. Collection of closed-face filter and respirable dust samples.

1. Assemble a sampling train consisting of a personal air sampling pump, a closed-face 37-mm filter cassette or 37-mm filter cassette with attached cyclone, and connecting tubing as shown below.

2. Assemble the two sampling trains using the pre-weighed cassettes and place the cassettes inside the dust generator.
3. Turn on the vacuum pump to activate the dust generator.
4. Wait approximately 30 seconds, then turn on both samplers and start a stopwatch.
5. Sample for five minutes, turn off the sample pumps, then turn off the vacuum pump for the dust generator.
6. Record all relevant information on the sampling form provided.
7. Gently remove the sampling devices from the dust chamber, taking care not to bump the filters against anything.
8. Take the samples to the Mettler balance; then, one at a time, remove the filters and weigh. (See part one for procedure)

Note: Weigh only the filter and not the support pad or the support pad and filter.

9. Record the weight as final weight.
10. Put the filter back into the cassette and place in the desiccator.
11. Clean the pumps, tubing, and cyclone sampler.
12. Desiccate the filters overnight, and then reweigh them.
13. Record the weight as desiccated weight.
TOTAL AND RESPIRABLE DUST GRAVIMETRIC ANALYSIS

<table>
<thead>
<tr>
<th>Sample ID #</th>
<th>Initial Weight (grams)</th>
<th>Sampling Rate (Lpm)</th>
<th>Sampling Duration (min)</th>
<th>Sampled Volume (liters)</th>
<th>Final Weight (grams)</th>
<th>Desiccated weight (grams)</th>
<th>Mass Collected (grams)</th>
<th>Mass Conc. (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALCULATIONS:

Note: For an example of calculations, see *FIH 6e Appendix A*.

Determination of sample volume: \( Qt = V \)
Where: \( Q \) is pump flow rate (Lpm); \( t \) is time (mins); and \( V \) is volume (liters)

Determination of concentration: mass collected / volume of air sampled.
Where: Mass collected is in mg and volume of air is in cubic meters.

Note: Pay attention to units. Make sure that answers are in the units requested. Also, calculate your weighing error for each sample from above:

Error calculations:

\[
\text{% Error} = \frac{[(\text{Observed} - \text{Expected}) / \text{Expected}] \times 100}
\]

Where: “Observed” is the measured weight of the filter prior to placing in desiccator and “Expected” is the actual or theoretical value.
Assume that the desiccated weight is the expected for your calculations.

Weighing error sample #1:

Weighing error sample #2:
Calculate the combined error for each of the samples using the weighing error you calculated and assuming a pump error of 5% and a timing error of 2%.

\[ E_{\text{combined}} = \left[ (a)^2 + (b)^2 + (c)^2 + \ldots (n)^2 \right]^{1/2} \]

Where: \( E_{\text{combined}} \) is in % and a, b etc are individual errors in %.

Combined error for sample #1 =

Combined error for sample #2 =
**Practical Exercise #2: Biological sampling**

**Procedure:**

I. Calibration of sampling pumps

1. Select a high flow air sampling pump. One capable of operating at 15 liters per minute.
2. Review the pump manual for calibration and operating instructions.
3. Using a high flow rotameter or dry calibrator and a dummy sample cassette assemble the system as shown in figure 1 *(DO NOT your sample cassette to calibrate the pump.)* Note: The square face is the inlet and should be open to the atmosphere.

![Diagram of sampling system](image)

**Figure 1**

*Note: The square face is the inlet and should be open to the atmosphere.*

4. Following the manufacturer’s instructions, adjust the pump to $15 \pm 1.0$ liters per minute (LPM).

II. Collection of sample

1. Identify a location which is likely to have pollen or fungal spore.
2. Mount the sampling pump on a tripod.
3. Set the sampling time to 5 minutes.
4. Mark an unopened sampling cassette with a unique identifier.
5. Take sampling train to selected sampling area.
6. Remove the top and bottom seals from the sample cassette and mount the cassette on the
pump.
7. Start the pump. Pump will automatically shut off at the end of the sampling period.
8. Replace the seals on the top and bottom of the cassette.
9. Return assembly to lab.
10. Using a dummy cassette, check the flow rate of the sampling pump.
11. Store cassette at location indicated by Instructor.

III. Analysis of a biological sample
1. Place one to two drops of stain (Lacto Phenol Cotton Blue) in the center of a clean pre-labeled microscope slide.
2. Slice through the labeling around the cassette and carefully open the cassette with a crowbar-style cassette opener.
3. The collection slide rests at four points inside the cassette inlet section; two points are fixed and visually marked. Use forceps to gently lift the side of the slide opposite the markings.
4. Ensure the orientation of the deposition trace is appropriate for analysis before mounting the collection slide. If the deposition trace is not visible, use the flat edges and orientation notches on the collection slide to position appropriately (see Figure 2). Slowly place slide at an angle with the media/sample side down onto the stain or mounting media. Do not press down. Use a cotton swab to remove excess stain or media after 10 minutes.

Figure 2

5. Use a microscope to view the particle deposition trace for quantification of sample components.
Review slide and record findings below:

Mold Spores Noted: Yes____ No____ If yes, Types______________
Pollen Spores Noted: Yes____ No____ If yes, Types______________

Note: For additional operational information on the Quick-Take, see *FIH 6e*, Appendix B.

Questions: To be answered in discussion section of write-up.

For results from Part A:

How did the results compare to the PEL, TLV, and RELs?

What health hazards would the identified levels present?

What precautions would be appropriate for the levels identified? Why?

What did your error calculation tell you about the need to desiccate the samples?

For results from Part B:

What biological materials were present?

What health hazards might the identified biological material present?

What precautions would be appropriate for the levels identified? Why?
Practical Exercise #3: Analytical methods

1. Go to www.cdc.gov and search the alphabet under N and find the NIOSH Manual of Analytical Methods. Using the alphabet at the bottom of the page, search the methods for the various chemicals listed below. Print just the first page and highlight the information requested for each.

Note: The minimum sampling time is not provided and must be calculated.

1. Formaldehyde by GC
2. Trichloroethylene
3. Benzene
4. Toluene
5. Asbestos and other fibers
6. Nuisance dust/particulate
7. Lead by flame ASS
8. Cadmium

Data Analysis and Interpretation:

Minimum information provided should include:

1. Method number
2. Sampler media
3. Sampling flow rate
4. Volume to be sampled
5. Minimum sampling time
6. Limits of detection (LOD)
7. Overall precision
8. Laboratory precision

2. For each method, explain ways in which the sampling and analytical method may impact sampling strategy.
Appendix A for Lab #4

HOW TO DETERMINE LAB RESULTS
(Example)

A) Time Start 8:00am
   Time Stop  8:10am
   Sample time = 10 minutes

B) Pre-sample calibration = 2.1 Liters per minute (Lpm)
   Post-sample calibration = 1.9 Liters per minute (Lpm)
   Average flow rate: (2.1 Lpm + 1.9 Lpm) / 2 = 2.0 Lpm

C) Sample volume: Qt = V
   From B: Q = 2.0 Lpm, From A: t = 10 minutes
   2.0 Lpm × 10 minutes = 20 liters

E) Convert liters to cubic meters (m³); 1000 liters = m³
   20 L × (1 m³ / 1000 L) = 0.020 m³

F) Mass collected: Final weight in grams (g) – initial weight in grams (g) = collected mass in grams. Assume initial weight of 0.0456 g and a final weight of 0.0512 g. Then mass collected = 0.0512 g – 0.0456 g = 0.0056 g

E) Convert grams to milligrams (mg); 1 g = 1000 mg.
   0.0056 g × (1000 mg / 1 g) = 5.6 mg

F) Mass concentration is mass collected / volume of sample.
   5.6 mg / 0.020 m³ = 280 mg / m³

CONVERSIONS

1000 L = 1 m³  1 g = 15.4 grains  1 atm = 760 mmHg
1 m³ = 35.3 cubic ft.  1 kg. = 2.2 lbs  760 mmHg = 29/92” Hg
1 ft³ = 28.3 liter   1 g = 1000 mg    1 atm = 407.5” H₂O
Laboratory #5
Detection of Gases
Laboratory # 5—Detection of Gases

Background:

In the atmosphere, gases tend to move from areas of high concentration to areas of low concentration. This process is independent of other mixing factors that are related to air movement (such as turbulent mixing). This principle is mathematically described by Fick’s Laws. This allows the prediction of the rates at which gasses will diffuse and is used to design diffusive samplers. This theory describes the relationships of gas properties and sampler dimensions in a steady-state atmosphere. Understanding the theory behind the practical application should allow you to better determine when passive sampling is appropriate to use.

Fick’s Law of Diffusion

\[ Q = DA \times \frac{(C_e - C_o)}{L} \]

Where:
- \( Q \) = Mass uptake in grams
- \( D \) = Coefficient of diffusion (\( \text{cm}^2/\text{sec} \))
- \( A \) = Cross sectional area of diffusion path (\( \text{cm}^2 \))
- \( t \) = Sampling time in seconds
- \( C_e \) = External concentration of gas being sampled
- \( C_o \) = Concentration of gas at interface of sorbant
- \( L \) = Length of diffusion path (cm)

From the formula it can be seen that the diffusive property of the gases affects the mass collected by the sampler (Q). The diffusion coefficients for a number of gases are readily available and are often published by the manufacturers of diffusive samplers. Like active sampling methods, the length of time samples and the concentration in the air affect the mass that is collected by the sampler. In the case of diffusive samplers, the difference between the concentration of the gas in the air and the concentration at the interface of the absorbent is directly proportional to the mass collected by the sampler. It should be noted that most times the concentration at the interface of the absorbent is effectively zero due to the rapid absorption rate of the absorbent. Thus, in the equation the term \( (C_e - C_o) \) would simplify to \( C_e \). From the formula it can be seen that the physical dimensions of the sampler determine, in part, the rate at which gasses will be collected by the sampler. Cross-sectional area (A) is directly proportional to the mass collected—i.e., the larger the area, the greater the mass collected. As a sampler gets close to its maximum capacity or if there are other gases present that are collected by the media blocking the collection sites on the media, a reduced rate of absorption by the sorbent can make \( C_o \) something other than effectively zero. This reduces the rate of collection of the sampler. High humidity can be one factor which affects the capacity of a sorbent. In addition to saturation and interference, care must be taken to assure that the environmental conditions do not exceed those recommended by the manufacturer so that the sorbent works as designed. As stated earlier, Fick’s Law as applied to diffusive samplers depends on steady-state conditions. One question to ask is: What happens if the concentration in the air varies over time (as you would expect it to in most work places)? The answer is that while fluctuations in concentration may slightly alter the rate of diffusion, as long as two conditions are met the fluctuations should not have a significant effect on the rate of collection.
These two conditions are: First, the absorbent does allow back diffusion of the collected gas (i.e., if the atmospheric concentration is lower than that at the interface, that gas does not move from the sorbent to the atmosphere), and second, the sampling time is well in excess of the time constant (the period of time that is takes the gas to diffuse to the sorbent). As the time constant for most commercial samples is less than 10 seconds, and recommended sampling times usually run 2 or more hours, this condition is generally met.

Face velocity is the movement of air across the face of the sampler. If there is no or very low air movement at the face of the sampler, gases collected will have to diffuse across additional space in order to be collected. This effectively increases the length of the diffusion path of the dosimeter (called boundary layer effect). Most dosimeters are designed for a minimum air velocity of 25 ft. per minute. This is about the velocity developed by a man walking at a normal pace.

At the opposite end of the spectrum, very high rates of air movement across the face of the sampler can cause turbulence in the dosimeter and effectively shorten the path length. Most dosimeters have a wind screen to eliminate this effect.

Colorimetric tubes and badges, also referred to as direct reading tubes and badges, are the most widely used direct reading devices due to their ease of use, minimum training requirements, fast on-site results, and wide range of chemical sensitivities. Colorimetric devices are based on instantaneous chemical reactions that produce a discernible color change. Some tubes contain a pre-layer that absorbs interferences. Tubes are used in combination with hand or automatic pumps. Different manufacturers design their pump specifically to be used with a specific design of tube. Interchanging equipment from different manufacturers will result in significant measurement errors. When a pump stroke is performed, air is drawn through the tube at the flow rate and volume determined by the manufacturer. The stroke volume is generally 100 milliliters, but the flow rate varies by manufacturer. A specific number of strokes is designated for each tube or detection range. This means the volume for a specific tube and scale are fixed. A change from the manufacturer’s instructions will result in inaccurate measurements.

Direct-reading instruments also referred to as real-time monitors, are among the most important tools available to industrial hygienists. Direct-reading instruments can be used to detect and quantify gases, vapors, and aerosols. These instruments allow for real-time or near real-time measurements of contaminants in the field, eliminating the need to send samples to the laboratory for analysis and the resulting delay in results. Direct reading instruments may be designed to monitor a specific gas or vapor (CO monitor), multiple gases or vapors (four gas meter), or a specific class of gases or vapors (combustible gas meter). All instruments are designed to be used within a designate detection range and require calibration before use. Direct-reading instruments may be designed for personal monitoring or area monitoring. Most monitors are designed to provide an emergency alert (often a combination of flashing lights and an auditory warning) when a critical level of a gas or vapor being monitored is exceeded. Instruments may include data logging that allows additional analysis of exposures after the data has been collected.

See *FIH 6e*, Chapter 17 for further details.
**Materials:**

Equipment:

- Draeger pumps
- Combustible gas/oxygen detector
- Personal sampling pump
- Bell jar and stand
- Passive tube holder
- Regulator and fittings

- Sensodyne, MSA pumps
- Tedlar sampling bag
- Tube opener
- Glass jar
- Four gas meter

Supplies:

- Colorimetric tubes (CO, CO₂, Ammonia, Alcohols, Polytec)
- Passive sampling tubes (CO or CO₂)
- Calibration gas
- Tubing

Vapor Sources:

- Isopropanol or ammonia
- Vehicle exhaust
- Candle

**Practical Exercise #1:** Passive monitor

**Procedure:**

I. Locate a *passive* sampling tube for carbon dioxide (CO₂) or Carbon Monoxide (CO).

   A. Read the instructions for determining the concentration of a gas with the passive sampler.
   B. Follow those instructions, and take a personal passive sample for the duration of the lab.
   C. While collecting the passive sample, proceed to Practical Exercise #2.
   D. At the end of the lab, record the requested information in the table below.

<table>
<thead>
<tr>
<th>Tube Used</th>
<th>Amount collected (PPM-HR)</th>
<th>Sample Time (hr)</th>
<th>Concentration. (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**CALCULATION:** PPM-HR / HR = PPM
**Practical Exercise #2:** Colorimetric tubes

**Procedure:**

**Part A**

I. Perform a leak check and flow calibration of a colorimetric tube pump.

   1. Insert an unopened detector tube into the detector tube pump.

   2. Draw the plunger back and release. If there is no plunger movement after 10 minutes, the seals are intact.

   3. If there is leakage, reseat the tube in the pump tip and retest. If the pump fails again, use a different pump or try to identify and correct the problem.

   4. Measure the concentration of a vapor specified by the lab instructor using an active sampling colorimetric tube with the following procedure:

      a. Pour a small quantity of solution onto the paper towels in the bottom of the glass bottle and seal the bottle with the top provided.
      b. Read the instruction sheet accompanying the detector tube kit.
      c. Prepare the colorimetric tube as specified in the instructions.
      d. Sample from the bottle by removing the top and measuring above the bottle. If the instructions specify a particular orientation for the tube, tilt or invert the bottle as necessary to keep the tube in the proper position. **Do not** put the tip of the sampler in the liquid.
      e. After sampling, each team member should independently read the concentration indicated by the color change without revealing their opinion to the others until all are finished. *Individual readings should be based on each person’s understanding of the tube instructions.*

   5. Exchange readings and record the results in the table below.

<table>
<thead>
<tr>
<th>Tube Used</th>
<th>Number of Strokes</th>
<th>Individual Readings</th>
<th>Average Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CALCULATION:

Average = \((C_1 + C_2 + C_3\ldots) / n\)

\(n\) = number of readings
\(C\) = individual readings

Part B

I. Measure the concentration of CO\(_2\) or CO as specified by the lab instructor using an active sampling colorimetric tube with the following procedure:

1. Read the instruction sheet accompanying the detector tube kit.

2. Prepare the colorimetric tube as specified in the instructions.

3. Light the candle and place the bell jar over the candle.

4. After the candle has guttered, collect a sample though the tube attached to the base of the bell jar.

5. After sampling, each team member should independently read the concentration indicated by the color change without revealing their opinion to the others until all are finished. Individual readings should be based on each person’s understanding of the tube instructions.

6. Exchange readings and record the results in the table below.

<table>
<thead>
<tr>
<th>Tube Used</th>
<th>Number of Strokes</th>
<th>Individual Readings</th>
<th>Average Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALCULATION:

Average = \((C_1 + C_2 + C_3\ldots) / n\)

\(n\) = number of readings
\(C\) = individual readings
Practical Exercise #3: Calibration and operational check of a 4 gas meter.

I. Calibration Four Gas Meter

5. Select a four gas meter
6. Review the operations manual for calibration and operating instructions.
7. Following the manufacturer’s instructions conduct the following:
   a. Zero the instrument
   b. Calibrate using the manufactures recommend calibration gas.
   c. Perform a calibration check
   d. Perform a functional test, sometimes referred to as a bump test.
   e. After successful completion of the above, note the instruments ID number. The calibrated and checked instrument should be used in the analysis of the bag sample collect in Exercise #4.
**Practical Exercise #4: Analysis of a bag sample**

**Procedure:**

I. Collection of a Bag Sample

A. Assemble a personal pump and tubing, as shown in Figure 1 below, to allow for the collection of an active air sample in a Tedlar™ bag.

![Figure 1](image)

B. Simulate sampling in an industrial environment.

1. Go to the parking lot, and insert the air intake tube into the exhaust of a vehicle.
2. Open the valve on the bag.
3. Turn on the vehicle, and turn on the personal pump.
4. Allow the pump to inflate the bag. Be careful not to over inflate the bag.
5. Close the valve on the bag. Turn off pump. Turn off car.
6. Once the sample is collected, return to the lab.

C. In the lab, screen the bag using an *active* sampling, polytech or equivalent, colorimetric tube as indicated by the lab instructor with the following procedures. Note: This is a qualitative tube that is commonly used as a screening method.

1. Read the instruction sheet accompanying the detector tube kit.
2. Prepare the colorimetric tube as specified in the instructions.
3. Carefully insert the inlet for the tube into the sample tubing connected to the bag.
4. Open the valve on the bag.
5. Collect sample as indicated by the instructions.
6. Close the valve to the bag.
7. After sampling, each team member should *independently* identify the chemicals indicated by the color change without revealing their opinion to the others until all are finished. *Individual readings should be based on each person’s understanding of the tube instructions.*
8. Exchange readings and record the results in the table on the next page.
D. In the lab, measure the concentration of CO as specified by the lab instructor using an active sampling colorimetric tube with the following procedure:

1. Read the instruction sheet accompanying the detector tube kit.
2. Prepare the colorimetric tube as specified in the instructions.
3. Carefully insert the inlet for the tube into the sample tubing connected to the bag.
4. Open the valve on the bag.
5. Collect sample as indicated by the instructions.
6. Close the valve to the bag.
7. After sampling, each team member should independently read the concentration indicated by the color change without revealing their opinion to the others until all are finished. Individual readings should be based on each person’s understanding of the tube instructions.
8. Exchange readings and record the results in the table below.

<table>
<thead>
<tr>
<th>Tube Used</th>
<th>Number of Strokes</th>
<th>Individual Readings</th>
<th>Average Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALCULATION:

Average = \( \left( C_1 + C_2 + C_3... \right) / n \)

\( n \) = number of readings

\( C \) = individual readings

E. Using the four-gas meter, perform a direct reading on your bag sample in the fume hood using the following procedure.

1. Disconnect the tube with the calibration attachment from the regulator.
2. Attach the tube to the bag sample.
3. Turn on the gas meter and connect the calibration attachment.
4. Open the valve on the bag and gently squeeze the bag.
5. Record the readings registered on the gas detector on the table below.
6. Close the valve on the bag.
7. Allow the detector to return to zero.
8. Turn off detector and reattach tubing to regulator.

<table>
<thead>
<tr>
<th></th>
<th>% O₂</th>
<th>% LEL</th>
<th>CO (ppm)</th>
<th>H₂S (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Practical Exercise #5: Comparison of Solid Sorbent Sample to Colorimetric Tube

I. Calibration of sampling pump
   1. Review NIOSH Sampling Method 1400.
   2. Select a low flow air sampling pump.
   3. Using a rotameter and a blank solid sorbent tube calibrate to 0.01 to 0.05 liters per minute.
   4. Determine minimum sampling time based on calibrated flow and method minimum sampling volume.

II. Preparation of test atmosphere.
   1. Mix 10 milliliters of 70% isopropanol (rubbing alcohol) with 1 liter of water.
   2. Pour the solution into a shallow dish and place in aquarium.
   3. Open a coconut shell charcoal tube, 100 mg/50 mg.
   4. Assemble Test Chamber as shown in Figure 2 below.

![Figure 2](image-url)
III. Collection of samples

1. Turn on pump and collect sample for number of minutes determined in Step 4 of Part I
2. Through the 2nd port collect a colorimetric tube while collecting sorbent tube sample.
3. After collection of sorbent tube sample remove from chamber and cap both ends of the tube.
4. After collecting the colorimetric sampling, each team member should independently read the concentration indicated by the color change without revealing their opinion to the others until all are finished. Individual readings should be based on each person’s understanding of the tube instructions.
5. Exchange readings and record the results in the table below.

<table>
<thead>
<tr>
<th>Tube Used</th>
<th>Number of Strokes</th>
<th>Individual Readings</th>
<th>Average Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

IV. Use the following formulas to calculate the expected concentration in the chamber based on the partial pressure of iso-propanol in the solution.

1. \( Pa = XaPv \)
   Where: \( Xa \) is the percent solution
   \( Pv \) is the saturated vapor pressure of the pure chemical.
   \( Pa \) is the vapor pressure of the chemical in solution.

2. \( ppm \text{ in mixture} = \frac{Pa}{Patm} \times 10^6 \)
   Where: \( Pa \) is partial pressure of chemical in mixture
   \( Patm \) is atmospheric pressure
V. Preparation and analysis of sorbent tube sample
1. Place the front and back sorbent sections in separate vial.
2. Add 1 ml of carbon disulfide w 1% 2-butanol to each vial and seal.
3. Allow to stand for 30 minutes with occasional agitation.
4. Prepare standards and blanks as per NIOSH method 1400.
5. Inject 5 microliters of the sample section into a GC/FID with the following conditions:
   a) Column 2 M x 4 mm ID 0.2 % carbowax 1500 or equivalent
      Injector temperature 200 °C
      Detector 250-300 °C
      Column 60-70 °C
      Carrier gas: 30 ml/min
6. Record data for front and back sections.
7. Generate a calibration curve using standard concentrations and peak area. (Refer to regression in Laboratory #2.)
8. Use calibration curve from standards (y = mx + b) to determine concentration in sample.
Practical Exercise #6: Questions

1. How does the CO reading from the passive sampler compare to the NIOSH “Chemical Hazards” specifications under the chemicals (i.e., TWA, IDLH, Health Hazards, PPE)?

2. What were the average value and the range of values represented by the team’s individual readings for the candle atmosphere sample?

3. For the candle atmosphere sample, did all team members use the same criteria for assessing the length of stain, i.e., did they all use the same area of the interface between the unreacted media and the well-defined color zone?

4. What systematic error would have occurred had the pump’s stroke volume not been consistent for the colorimetric tube samples?

5. For the candle atmosphere sample, were there differences between the estimates of concentration? If so, why?

6. How do the estimates of concentration for the bottle and candle samples compare to the respective PELs and TLVs?

7. What chemicals were identified as possibly present in the bag sample?

8. What are the hazards associated with the chemicals identified in the bag sample?
9. What additional tests would you perform for the chemicals identified in the bag sample?

10. How do your colorimetric tube CO readings for the bag sample compare to the NIOSH “Chemical Hazards” specifications under the chemicals (i.e., TWA, IDLH, Health Hazards, PPE)?

12. How do your direct-reading instrument readings compare to the NIOSH “Chemical Hazards” specifications under the chemicals (i.e., TWA, IDLH, Health Hazards)?

13. What PPE would be required for the individual working in this environment? Why?

14. How did the colorimetric tube concentration and the sorbent tube concentration compare to the expected concentration? Explain any differences.

15. Using the error calculation from Laboratory 4 what was the error for the two sampling methods?

16. How do your errors compare to the reported accuracy of the two methods?
Laboratory #6
Ventilation
Laboratory # 6—Ventilation

Background:

Ventilation is the process of supplying air to or removing air from a space for the purpose of controlling air-contaminant levels, humidity, or temperature within the space (ASHRAE 62-2001). Properly applied, ventilation will maintain IAQ at acceptable levels. Acceptable indoor environmental quality is defined as air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities. The majority of people (80% or more) exposed have little or no dissatisfaction with air quality.

Ventilation systems are often designed to serve a specific purpose. This may range from supplying oxygen and/or removing contaminants in a confined space to providing a comfortable work environment in an office by controlling temperature and humidity. Systems may be designed as a dilution system or a local exhaust system. Highly toxic compounds or contaminants that have the potential to present a significant risk are generally handled by local exhaust systems. Local exhaust systems trap air contamination near the source. This prevents the contaminant from moving beyond the site of generation, thus reducing the risk of exposure. Local exhaust only provides ventilation at a specific location. Most sites require a dilution ventilation system in addition to local exhaust or just a dilution system alone such as those found in a manufacturing shop. Dilutions systems can be used when the contaminants are at low levels and present little or no risk.

Materials:

Manometer  Model ventilation system
Balometer  Anemometer
Laboratory hood  Dry bulb thermometer
Tape measure

Practical Exercise #1: Characterization of air velocity and pressure with a model ventilation system

Procedure:

1. Review the model ventilation system layout in Figure 1 on the next page. Note the location and numbering of the measurement provided.
2. Place cap at point A on end of the pipe. Take a reading at points 1–10. Record data in Table 1.

   Note: Check manometer for units and use the same manometer for all measurements.

3. Take cap off and repeat Step 2.

4. Remove elbow X, place cap at point B, and repeat Step 2 for points 1–6.

5. Remove elbow Y, place cap at point C, and repeat Step 2 for points 1–2.

6. Average the pressure readings. Calculate total pressure, velocity, and volumetric flow rate for each condition.
Table 1

I. Cap on

<table>
<thead>
<tr>
<th>Static Pressure (SP)</th>
<th>Velocity Pressure (VP)</th>
<th>Velocity (f/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
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<tr>
<td>7.</td>
<td>8.</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>10.</td>
<td></td>
</tr>
</tbody>
</table>

Average SP _____  Average VP _____  V = __________

Total Pressure = TP = ____.
Flow Rate (cfm) = Q = ________.

II. Cap off

| Point A              |                        |                  |
| 1.                    | 2.                     |                  |
| 3.                    | 4.                     |                  |
| 5.                    | 6.                     |                  |
| 7.                    | 8.                     |                  |
| 9.                    | 10.                    |                  |

Average _____  Average _____  V = __________

Total Pressure = TP = __________.
Flow Rate (cfm) = Q = __________.

III. Cap on

| Point B              |                        |                  |
| 1.                    | 2.                     |                  |
| 3.                    | 4.                     |                  |
| 5.                    | 6.                     |                  |

Average _____  Average _____  V = __________

Total Pressure = TP = __________.
Flow Rate (cfm) = Q = __________.
IV. Cap off

Point B
1. ____________
2. ____________
3. ____________
4. ____________
5. ____________
6. ____________

Average _____ Average _____ V = _________

Total Pressure = TP = __________.
Flow Rate (cfm) = Q = __________.

V. Cap on

Point C
1. ________
2. ________
V = ________

Total Pressure = TP = __________.
Flow Rate (cfm) = Q = __________.

VI. Cap Off

Point C
1. ________
2. ________
V = __________

Total Pressure = TP = __________.
Flow Rate (cfm) = Q = __________.

CALCULATIONS:

A. Calculate total pressure using the formula:
   TP = VP + SP; where
   TP = total pressure
   VP = velocity pressure
   SP = static pressure

B. Compute velocity pressure using the formula:
   \[ V = 4005 \times \sqrt{VP} \]
   where
   V = velocity, feet per minute (fpm)
   VP = velocity pressure, inch in water gauge

C. Compute cross-sectional area using formula:
   \[ \text{AREA} = \pi r^2 \]
   where:
   r = the radius of the duct
   2r = d; d = diameter
Example: Area of 2 in diameter duct = $\pi r^2 = (3.146) (1)^2 = 3.146 \text{ sq. in}$

Convert to sq. ft.: 1 ft. = 12 inches; 1 ft.² = 144 in²

$(3.146 \text{ sq in}) = \frac{1 \text{ sq. ft.}}{144 \text{ sq in}} = .0218 \text{ sq. ft.}$

D. Compute Flow Rate using the formula:

$$Q = VA, \text{ where}$$

- $Q =$ volume flow rate, cubic feet per minute (cfm),
- $A =$ cross sectional area of duct, square feet (sq ft),
- $V =$ average velocity, feet per minute (fpm)

Practical Exercise #2: Measurement of velocity and air flow in an exhaust hood

Procedure:

1. Turn on the anemometer and set to slow response.

   Note: Anemometer readings are orientation dependent Make sure to have the probe perpendicular to flow and on a level plane.

2. Set the hood sash at normal operating height (generally where the fixed stop is set).
   Record hood type and serial number.

3. Measure the dimensions of the hood opening (length and height) and record below.

4. With both doors of the laboratory room closed, use the anemometer to obtain readings from the nine locations as shown in Chart 1.

5. Open both laboratory doors and repeat Step 3.

6. Calculate the average velocity at the hood face.

7. Calculate the volumetric flow rate through the hood.

   **CHART 1**

A) Linear feet per minute(lfpm) — Both room doors closed:  

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>C</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
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<td>C</td>
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</tbody>
</table>

Average with doors closed _____ lfpm

B) Readings(lfpm) — Both room doors open:  

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>C</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average with doors open _____ lfpm

82
Equipment Description:

Dimensions of hood opening: Length _______ Height__________

Calculations:
A = length × height Q = VA
Where: Average Ifpm for A: ______
Q = volumetric flow rate in cubic feet per minute Average Ifpm for B: ______
V = velocity in feet per minute Average Q for A: ______
A = cross-sectional area in square feet. Door opening to obtain 100 Ifpm: ______

Practical Exercise #3: Measurement of volumetric flow of room air

Procedure:

1. Measure room dimensions in feet: Length _____ Width _____ Height____

2. Using the balometer, measure air flow (Q) into the room from every air duct in cubic feet per minute (cfm) and record below.

   Q1 = _____  Q2 = _____  Q3 = _____  Q4 = _______

3. Review the room ventilation schematic and determine the flow rate indicated by the design specification.

   Q1 = _____  Q2 = _____  Q3 = _____  Q4 = _______

CALCULATIONS:

A. Calculate the room volume in cubic feet = RV = L × W × H = _______.

B. Calculate Total Air Volume based on measured flows:

   Total Air Volume = Qt = Q1 + Q2 + Q3 + Q4 =_______________ cfm

C. Calculate Air Changes per Hour: ACH = Qt (cfm) ÷ RV (ft³) × 60min/hr = ACH _______

D. Calculate number of minutes to exchange volume of air in the room at least twice.

   Time required to completely change out air in room twice = ______________
5. If there were 40 students in the room and, according to ASHRAE, you needed 15 cfm per person, would you be introducing enough air into the room?

\[
40 \text{ students} \times 15 \text{ cfm/student} = \text{__________}
\]

(From #2) \(Q_t = \text{__________} : \) Is this enough air? Yes _____ No ______

Units:

- CFM = cubic feet per minute
- RV = room volume in cubic feet
- ACH = Air changes per hours

Formulas:

\[Qt = V\]

Where: \(Q = \) Flow rate (cfm), \(t = \) time (minutes); \(V = \) volume (ft\(^3\))

**Practical Exercise #4: Questions**

1. How does the laboratory hood compare to the design requirements (Part 2)? Reference page 432 in *FIH 6ed* to determine adequate flow rates for a Type B2 biological safety cabinet.

2. Based on the data, what problems are there with the hood flows?

3. Provide recommendations to correct any identified problems with the hood system.

4. How do the volumetric flow rates of the HVAC system (Part 3) compare to the design specs of the ventilation system?

5. Explain why there is a difference between the HVAC design and measured duct flow rates.
Additional Information for Ventilation Lab

**Description of model ventilation systems:** System consists of small electric blower attached to 3 sections of 2” PVC pipe. Each section is joined together with a 180 degree coupling, and the last section is fitted at the end with a reduced flow cap. Each individual section of pipe can be removed and capped to show varying degrees in velocity and air pressure caused by changes in duct length and direction.

**Sampling devices and procedures:** Static pressure and maximum velocity are recorded using a Pitot Traverse measurement of velocity along the length of the duct. Two Dwyer Mark II Manometers are attached by plastic tubing to pitot tube fittings set into the duct pipe at 2 foot intervals, with one fitting on each elbow point. Pressure is read in inches/water gage, using the Manometer. Use only .826 specific gravity red gage oil in the Manometer, Model 25 as per the instruction sheet.
Laboratory #7
Dermal Exposure
Laboratory #7—Dermal Exposure

**Purpose:**
The purpose of the dermal exposure lab is to demonstrate the various mechanisms of dermal exposure, and to discuss the various methods to assess dermal exposure. Additionally, various PPE will be assessed to evaluate the ability of PPE to prevent or reduce dermal exposure.

**Materials:**
Safety glasses
Gloves
Uvitex powder
Uvitex liquid
Spray bottle
Paper towels

**Practical Exercise #1:** Perform the following exposure assessment.

**Procedure:**

**Safety glasses must be worn at all times.** This lab uses Uvitex liquid to simulate a typical cleaning task. Uvitex is a black light fluorescing compound. Prior to the start of the exercise, all members of the groups should be screened by black light.

After the black light screening is completed:

- Select two individuals from each group to serve as test subjects.
- Select one individual to serve a director.
- Select two individuals to serve as observers.

The director will:

- Provide instructions for the cleaning task to be performed.
- Monitor the cleaning technique and make note of the body areas exposed during the cleaning task.

Observers will:

- Monitor the cleaning task and note the body areas exposed during the cleaning technique.
- The observers and the director should be arrayed so that all sides of the test subject can be observed.

Test subjects will:

- Perform a simulated cleaning task under the direction of the director.
- One test subject will use disposable gloves.
- The second test subject will not wear gloves.
The test subjects will simulate a cleaning task by using the bottle of Uvitex liquid to “clean” a surface with paper towels until all of the solution is consumed. The test subjects will perform the task, one after the other. The director and observers will note where the test subjects appear to have been contaminated.

Test Subject #1:

Test Subject #2:

Next, all individuals in the group will be re-screened by black light to identify areas of contamination.

Test Subject #1:

Test Subject #2:

Others Contaminated:
**Practical Exercise #2:** Answer the following questions.

1. Did the simulated cleaning task result in any exposure to you or your group? If so, where and who was exposed?
2. What areas of the body received the highest level of exposure from the simulated cleaning task? Why?
3. Which individual(s) had high exposure during the simulated cleaning task? Why?
4. Did the individual who wore gloves while performing the simulated cleaning task have any exposure? Why or why not?
5. Thinking critically about the exposures observed in this lab, what other types of exposures (non-chemical) and routes of exposure could the methods used in this lab represent?
6. Using various resources, including your text, identify at least three methods for assessing dermal exposure or potential for dermal exposure to solvents, pesticides, and heavy metals.
7. What are some general guidelines for using these methods that you identified? (Hint: Where is exposure assessed? Think about the quantity of the area sampled).

8. Was the exposure assessment technique used in the lab a quantitative or qualitative method? Explain your answer.

9. Could this laboratory technique be used to quantitatively assess dose? If so, how?
Laboratory #8
Thermal Stresses
Laboratory #8—Thermal Stresses

Background:

Often within the commercial and industrial environment, the employee is subjected to extreme temperatures. In many cases, the strain is such that the body’s thermal regulating functions cannot act to remove the heat build-up rapidly enough. Excessive heat stress can result in a physiological and psychological strain on the exposed worker. The amount of heat stress present in a work environment is a function of certain environmental measures, i.e., the air temperature, the air humidity, the radiant heat load, and the air movement. Psychologically, the individual exposed to heat stress becomes edgy and fatigued while accomplishing a given task. Additionally, stress can be a result of certain physiological conditions involving the worker. These conditions may include the employee’s amount of acclimatization (progressive exposure to hot environments to allow adjustment), clothing, age, sex and physical condition. Evaluation of environmental conditions can be done in order to predict the effects on individuals. The self-contained heat stress monitor alone is not sufficient to determine the level of heat stress. The measurements must be equated with the individual’s various physiological strains encountered within the hot environment to provide a baseline for introducing controls on heat exposure(s). The total heat stress can be reduced by modifying one or more of the following factors: metabolic heat production, heat exchange by convection, heat exchange by radiation, or heat exchange by evaporation. The environmental heat load can be modified by engineering controls: ventilation, air conditioning, screening, insulation, work operation modification, and protective clothing and equipment. See FIIH 6e, Chapter12, for additional information on thermal stress.

Materials:

Equipment:

- QUESTEMP ° 10™
- Heat lamp
- Tripod, adjustable height
- Tape measure
- Hot Plate
- Pan
- Calibration sensor module
- Sling psychometer
- Fan

Supplies:

- Battery, 9 Volt
- Distilled water
- Cardboard
- Tap water

Practical Exercise #1: Heat stress measurement

Procedure:

I. Laboratory setup
   a. Place the hot plate, heat lamp, and fan under the laboratory hood.
b. Fill the pan with tap water and place on the hot plate.
c. Turn on the hot plate. (Boiling water represents humid conditions)

Note: It will take some time for water to boil, so do this at the start of the lab period.

d. Turn on the heat lamp (radiant heat condition).
e. Turn on the fan.

II. Check calibration of QUESTEMP heat stress monitor.
   a. To check the calibration, remove the top sensor assembly by unscrewing the two black knurled knobs and plug in the module.
   b. With the unit set to read in degrees Celsius, depress the GLOBE, DRYBULB, and WETBULB keys and verify that the readings match those printed on the module within (+ / −) 0.5°C.
   c. Repeat when all measurements are completed.

III. Data collection in laboratory
   a. Before collecting data, wet the wet bulb wick of the QUESTEMP heat stress monitor with distilled water from the squeeze bottle.

   Note: You do not have to fill the cup up, just get the wick and sponge wet.

   b. In the laboratory, turn on QUESTEMP heat stress monitor. Wait 15 minutes, and then record under the normal column in Table 1 below the Dry Bulb, Globe, Wet Bulb, and WBGT\textsubscript{in} temperatures.
   c. While waiting for the QUESTEMP heat stress monitor to stabilize, wet the wet bulb wick on the sling psychometer.
   d. Spin the sling psychometer for at least 1 minute before reading.
   e. Record the Dry Bulb, Wet Bulb, and relative humidity in the appropriate column in Table 1 on page 85.
   f. Place QUESTEMP heat stress monitor under the hood below the heat lamp and in the path of the steam from the boiling water. Wait 15 minutes, and then record under the Humid, Radiant Fan column in Table 1 below the Dry Bulb, Globe, Wet Bulb, and WBGT\textsubscript{in} temperatures.
   g. Adjust conditions as indicated in the table and repeat Step f.
   h. Turn off equipment when complete.

   Note: Use provided cardboard to shield the monitor from the direct light of the heat lamp for the shielded condition.

IV. Data collection in an outside environment
   a. Mount the QUESTEMP heat stress monitor on a tripod.
   b. Move the QUESTEMP heat stress monitor and tripod to a site outside the building into direct sunlight.
c. Record the Dry Bulb, Wet Bulb and relative humidity in the appropriate column in Table 1 below.
d. Wait 15 minutes, and then record under the Outside in direct sunlight column in Table 1 below the Dry Bulb, Globe, Wet Bulb and WBGT<sub>out</sub> temperatures.
e. Move the equipment to the shade and repeat Step c.
f. Turn off the equipment when complete.

V. Using the two Heat Stress Alert Limit tables, assume each of the locations represented in the data table represents a work situation. Select the exposure limit (work-rest cycle) for each that would be appropriate for an individual expending energy at a rate of 1600 BTU/hr. Record in Table 1.

VI. Sling psychometer

a. Wet the Wet Bulb wick on the sling psychometer.
b. Spin the sling psychometer for at least 1 minute before reading.
c. Record Dry Bulb and Wet Bulb temperatures.
d. Using the sling psychometer, calculate the relative humidity.

Additional Information:

When making an area heat stress measurement, the monitor should be placed at a height of 3.5 feet for standing workers or 2 feet for seated workers in the area.

Do not stand close to the unit during sampling.

When placing the unit in a new environment or adding distilled water to Wet Bulb, allow fifteen minutes for unit direct readings to stabilize.

Make sure that the Wet Bulb reservoir is filled with distilled water.

Turn the unit off when finished.
<table>
<thead>
<tr>
<th>CONDITION</th>
<th>NORMAL</th>
<th>HUMID &amp; RADIANT</th>
<th>HUMID &amp; RADIANT</th>
<th>HUMID, RADIANT, SHIELDED</th>
<th>OUTDOORS, IN DIRECT SUN</th>
<th>OUTDOORS, IN SHADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Velocity</td>
<td>N/A</td>
<td>FAN</td>
<td>W/O FAN</td>
<td>FAN</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>WBGT Apparatus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globe (t_g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Bulb (t_a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Wet bulb (t_{nwb})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Calculated Indices</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>WBGT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Recommended Heat - Stress Exposure</strong></td>
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<td></td>
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<tr>
<td><strong>Psychrometer</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychrometric dry bulb (t_a)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychrometric wet bulb (t_{wb})</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Relative Humidity’s</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From Sling Psychrometer</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Practical Exercise #2: Reading the psychrometric chart

Procedure:

Find the missing values on the following chart:

<table>
<thead>
<tr>
<th>Dry Bulb</th>
<th>Wet Bulb</th>
<th>Relative Humidity</th>
<th>Dew Point</th>
<th>Moisture Content</th>
<th>Humid Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>50</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>90</td>
<td>80</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td>13.7</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>30</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Practical Exercise #3: Questions—circle the correct answer.

1. The one factor not affecting heat stress is:
   A. Dehydration
   B. Loss of sleep
   C. Blood type
   D. Obesity
   E. Acclimation

2. Relative humidity is determined by which two temperature measures:
   A. Wet bulb and dry bulb temperatures
   B. WBGT and globe temperature
   C. Dry bulb and globe temperature
   D. Wet bulb and globe temperatures
   E. None of the above

3. Relative humidity is defined as ____________.
   A. the ratio of wet bulb and dry bulb temperatures
   B. the ratio of wet bulb and globe temperatures
   C. the ratio of the partial pressure of water vapor to the saturated vapor pressure of water in the air
   D. A and C
   E. None of the above

4. In heat stroke, the ____________.
   A. body temperature is lowered
   B. body temperature is elevated
   C. body temperature is normal
   D. patient sweats profusely
   E. None of the above

5. Radiant heat, a form of electromagnetic energy, ____________.
   A. is not important in heat stress
   B. is best controlled by absorbent materials
   C. does not heat the air
   D. can be controlled by cool air blasts
   E. None of the above

6. What is the main part of the body involved in maintaining the body’s heat balance?
   A. Skin
   B. Heart
   C. Lungs
   D. Hair
7. What factor least influences the interchange of heat between man and his environment?

A. Moisture content of the air
B. Air velocity
C. Air density
D. Air temperature
E. All above are equal

8. How often do you verify the calibration of the heat stress monitor?

A. At end of each yearly quarter
B. Before and after sampling, and at least annually
C. Self-contained unit, not required
D. Before each lab sampling
E. When first purchased

9. Which is an example of administrative controls for control of heat exposure?

A. Decrease of the work required
B. Modify the worker’s exposure, including rest schedules
C. Education and Training
D. All of the above
E. None of the above

USING THESE FORMULAS, ANSWER THE QUESTIONS BELOW:

°C = 5/9 (°F – 32)

°F = (9/5 °C) + 32

10. Given a temperature of 30°C, what is the equivalent in °F?

A. 65°F
B. 86°F
C. 79°F

11. Given a temperature of 87°F, what is the equivalent in °C?

A. 30.6 °C
B. 28.0 °C
C. 25.6 °C
Laboratory #8 Appendix A

QUESTEMP °10™ FEATURES

The large liquid crystal display indicates the selected temperature reading in degrees Celsius or Fahrenheit. The test’s measurement conditions must be selected using the following keys:

**WBGT OUT** Depressing this key displays the outdoor WBGT weighted index of 0.7WB + 0.2G + 0.1DB.

**WBGT IN** Depressing this key displays the indoor WBGT weighted index or 0.7WB + 0.3G.

**°C/°F** Depressing this key causes the displayed temperature or WBGT index to switch between either degrees Celsius or degrees Fahrenheit.

**GLOBE** Depressing this key causes the GLOBE temperature to be displayed. The blackened globe temperature is correlated to that of a 6-inch diameter globe.

**DRYBULB** Depressing this key causes the DRYBULB (ambient air) temperature to be displayed.

**WETBULB** Depressing this key causes the natural WETBULB (humidity and wind speed) temperature to be displayed.

**ON/OFF** Depressing this key will turn power to ON. Depressing this key a second time will turn power to OFF. Remember to turn off when not using.

**LOBAT** This key flashes for low battery indicator.

**BATTERY REPLACEMENT:** The LOBAT indicator on the display shows when the battery should be replaced. To replace the 9 Volt battery, open the compartment at the back by lifting one end of the black plastic cover. If the unit is to be stored for an extended period, REMOVE THE BATTERY from the unit before returning to case. The battery life is typically 150 hours.

**CALIBRATION:** *Before* (and *recheck* after) each test, unit calibration must be verified by using the black Calibration Sensor Module. To check the calibration, remove the top sensor assembly by unscrewing the two black knurled knobs and plug in the module. With the unit set to read in degrees Celsius, depress the GLOBE, DRYBULB, and WETBULB keys and verify that the readings match those printed on the module within (+ / −) 0.5°C. Unit must be returned to factory for recalibration.
SENSORS USAGE:

**NATURAL WET BULB THERMOMETER**

The Natural Wet Bulb Thermometer gives an indication of the effects of humidity on an individual. Relative humidity and wind speeds are taken into account by measuring the amount of evaporation cooling taking place at a thermometer covered with a moistened wick. The cotton wick in the plastic reservoir must be fully immersed in *distilled water*. Ordinary tap water must not be used due to contaminants that are left behind after evaporation. Contaminants will shorten the life of the wick and cause high readings. Also, if the wick becomes discolored, it should be replaced. To replace the wick, slide the old one off and sponge off the top of the sensor with distilled water. Place a new wick over the sensor, making sure that the bottom of the wick is down in the reservoir. Slide the sponge over wick and into reservoir.

**GLOBE THERMOMETER**

The globe thermometer gives an indicator (provides an indication or is an indicator or measure) of the radiant heat exposure to an individual due to either direct light or hot objects in the environment. This is accomplished by the placement of a temperature sensor inside the blackened copper sphere and measuring the temperature rise. The reading is based on the response of the “6 inch diameter globe” theory. This unit uses a correlated 2-inch diameter globe for a faster response time.

**DRY BULB THERMOMETER**

The dry bulb thermometer measures the *ambient air temperature*. This measurement is used in the outdoor WBGT calculation when a high solar radiant heat load may be present.
Laboratory #9
Noise Control
Laboratory #9—Noise Control

Background:

Hearing loss was first observed in 1700 and was documented by Ramazzini in one of his works that described how workers hammering copper injured their hearing. With the rise of the industrial revolution, hearing loss has become more prevalent, and therefore, the need to control loud workplace environments has also become apparent. Understanding sound, its movement through the environment, the measurement of sound levels, and possible control methods will allow the Industrial Hygienist to recognize, evaluate, and control a leading hazard in the workplace.

Purpose:
The purpose of this project is to demonstrate the effectiveness of acoustic materials and other methods in controlling noise.

Theory:
The first step in noise control is to secure adequate quantitative and qualitative information on the extent and magnitude of the problem. This requires extensive noise measurements and a complete description of the environment.

Determine amount of reduction necessary for adequate control of potential noise problems. It must be emphasized that in order to control noise, relatively large reductions in energy must be achieved. Cutting energy in half reduces the sound pressure level by only 3 dB. For this reason, noise control is usually expensive, and it is important to understand the problem thoroughly before attempting to institute controls.
Materials:

- Sound level meter type II
- Acoustic calibrator, MSA P/N 695094
- 5 batteries, 9 Volt
- Acoustic foam pieces and manufacturer data
- Wooden boxes #1 and #2
- Bell (noise source)
- Chart and pencil

Practical Exercise #1: Sound meter calibration

Procedure:

I. Use the MSA sound level calibrator (114 dB) to calibrate the realistic sound level meter, Type II.
   A. Test the battery on the calibrator and SPL.
   B. Set SPL to A scale, slow response, and 110 dB.
   C. Insert SSPL into the calibrator and turn the calibrator on. Record response.

II. Use the Quest permissible sound calibrator (110dB) to calibrate the realistic sound level meter, Type II.
    A. Test the battery on the calibrator and SPL.
    B. Set SPL to A scale, slow response, and 110 dB.
    C. Insert SPL into the calibrator and turn the calibrator on. Record response and adjust with screw driver.

Data Analysis and Interpretation:

Comment on the accuracy of the Quest and MSA calibrations for pure tones.
**Practical Exercise #2:** Noise control—bell alarm

**Procedure:**

I. Laboratory setup:

   A. Locate the sound level meter.
      
      2. Follow all safety rules while performing test. Remember to wear PPE when collecting noise measurements.
      3. Position meter to read noise at 1 ft. and 4 ft. from source.
      4. Obtain “Bell Alone” reading #1 on a table to simulate a sound source mounted on hollow-base equipment.
      5. Obtain “Bell Alone” reading #2 on a concrete floor to simulate a sound source mounted, or in Q2 position.
      6. Set up the remaining 10 readings using both boxes in both locations. Refer to attached bell alarm exercise #2 under the configuration column for positions with and without foam.

   B. Answer the following questions.
      
      1. What did the Q2 position reflect?
      2. What does the foam usage reflect in the readings?
      3. Use the SPL distance formula to compare the measured sound levels in the different positions between 1-ft. and 4-ft. measurements.
         
         \[
         \text{Distance} = \text{SPL}_{d_2} = \text{SPL}_{d_1} + 20 \log \left( \frac{d_1}{d_2} \right)
         \]
      4. Using the “Noise Control: A guide for workers and employers” (published by the U.S. Department of Labor Occupational Safety and Health Administration) recommend solutions for introducing noise control in the table position that simulates a hollow base.
**BELL ALARM EXERCISE #2**

Facility: _______ Time: _______ By: _______

Location: _______ Temp: _______ Date: _______

Equipment Description:

Instrument (model-S/N) used:

<table>
<thead>
<tr>
<th>Reading No.</th>
<th>Box No.</th>
<th>Location</th>
<th>Configuration</th>
<th>1 ft dBA</th>
<th>4 ft dBA</th>
<th>Calculated SPL at 4 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Table</td>
<td>Bell-alone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Floor</td>
<td>Bell-alone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Table</td>
<td>Foam on Bottom and Lid Open</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Table</td>
<td>Foam on Bottom and Lid Closed</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>Floor</td>
<td>Foam Bottom/Sides and Lid Open</td>
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Note: How did the calculated change in sound levels compare to actual measurements?
Define the following terms and acronyms:

NIHL:

Frequency:

Noise:

TTS:

PTS:

At what frequency range does noise-induced hearing loss usually first show up on an audiogram?

A. low frequencies (250–1000Hz)
B. high frequencies (3000–6000 Hz)
C. equal distribution (250–8000 Hz)
D. no specific frequency

An annoying noise is 73 dBA at a distance of 300 ft., what is the sound pressure level at 75 ft.?

A. 76 dBA  
B. 79 dBA  
C. 85 dBA  
D. 97 dBA

PRACTICAL EXERCISE #3: Hearing test

Procedure:

1. Using the audiometer and sound booth, test the hearing (both right ear = X and left ear = O) of each member.

2. Record results on audiogram and comment on the results.
Laboratory #10
Radiation
Laboratory #10—Radiation

RADIATION DOSIMETER SYSTEM

Purpose:
To provide a framework within which the safety of ionizing radiation conditions can be evaluated.

Theory:
Radiation safety should be part of a company’s total health and safety program. The introduction of radiation devices or radioactive materials usually calls for radiation safety reviews, engineering controls, and plant modifications. Traffic patterns for pedestrians and mobile equipment may need to be altered to minimize the spread of radioactive materials in the event of an accident.

Radiation sources include:

1. NATURAL—examples include cosmic radiation from space, gamma radiation from natural materials (e.g., uranium) and building materials (e.g., radon gas from some types of sheetrock).

2. ENVIRONMENTAL—examples include fallout, electronic equipment, and effluent from nuclear reactors and processing plants.

3. MEDICAL—examples include X-rays, therapeutic irradiation, and ingested or injected radionuclides.

4. OCCUPATIONAL—numerous sources (e.g., military)

The pocket dosimeter is a direct-reading portable unit shaped like a pen with a pocket clip. The dosimeter consists of a quartz fiber, a scale, a lens to observe the movement of the fiber across the scale, and an ionization chamber. The fiber is charged electrostatically until it reaches zero on the scale. Then, as the dosimeter is exposed to radiation, some of the air atoms in the chamber become ionized. This allows the static electricity charge to leak from the quartz fiber in direct relationship to the amount of radiation present. As the charge leaks away, the fiber deflects to some new position on the scale that indicates the amount of radiation exposure.

Personal dosimeters are intended to measure radiation exposure to the wearer. For maximum efficiency, personal dosimeters should be worn near the part of the body with the greatest potential of exposure and/or the greatest sensitivity to radiation. The main advantage of wearing this device is that it allows radiation dose determination immediately rather than waiting until after periodic processing of a film badge or thermoluminescent dosimeter.
Practical Exercise #1:

Materials:

Pocket direct gamma and e-ray dosimeter, Model 862  
Dosimeter charger, Model 909  
Battery, size D  
Dosimeter logbook, Model 1102

Procedure:

1. Locate equipment per the materials list.  
2. Follow all safety rules while performing tests.  
3. Read instruction sheets on both the dosimeter and charger.  
4. Charge (zero kick) the self-reading pocket dosimeter per instructions before beginning the lab exercise.  
5. Clip the dosimeter onto the test subject. The exercise is to be performed at a location identified by the instructor.  
6. After the exercise, read the dosimeter per the instructions. Enter the exercise facility data, test subject’s Social Security number for identification, and the radiation dose/exposure on the log sheet. Several companies are currently using computer software to record annual data per S/N of employee.  
7. What was the source of radiation for the exercise?  
   a. Naturally occurring process (i.e., radon)  
   b. Radioactive decay of industrial or medical radioisotopes  
   c. X-ray machines (i.e., medical or weld test machines)  
   d. Accelerators  
   e. Any other source  
8. What is the annual individual dose exposure for that source?
Laboratory #11
Measurement of Illumination
Laboratory #11—Measurement of Illumination

**Purpose:**

To use certain methods and techniques to get the illumination present in a work area.

**Theory:**

The main objective of illumination in the industrial environment is to provide good visibility and satisfactory eye comfort. Eye fatigue is a result of poor illumination, along with decreased production, more rejects of finished products, and increased accidents. It also can affect worker morale.

The four factors that determine the quality of the illumination are:

1. Size of the object worked with
2. Time available to perform the task
3. Contrast
4. Brightness level to which the object is illuminated

Color, direction, brightness, diffusion, glare, and reflectance are all quality factors of illumination. Each of these has a large effect on the visibility and the ability to see easily, accurately, and quickly. Frequent cleaning of skylights and windows may also prove helpful. A newly identified problem is the glare upon the computer screen in relationship to the computer operator’s work position.

The amount of light in a room is measured in “lumens”. Illumination is measured in “foot-candles”. The foot-candle is one lumen per square foot. Transmittance and reflectance is measured in “percent”.

**PRACTICAL EXERCISE #1**

**Materials:**

- Digital foot-candle meter, GREENLEE Model 93-1065
- Battery, 9 Volt
- Mirror
- Construction paper
- Plastic sheets
- Yard stick
- Portable small lamp
- Tape measure
- Engineering graph paper and pencil
Procedure:

Measurement of Illumination

Locate equipment per the Dermal Exposure Assessment in Laboratory #7:

A. Review materials list and identify the room where exercise will be performed.
B. Follow all safety rules while performing tests.
C. Read instruction manual for “Operating Procedures”.
D. Make calibrations on the light meter and check battery.
E. Measure and compile a plot plan of the room showing entrance(s), windows, light fixtures, footage, and work area locations(s).
F. Perform each lab exercise.

Illumination, Transmittance, and Reflectance

A. Illumination in the room should be taken about 30 inches above the floor to simulate the desk height. Readings to be taken from 12 different areas. Add the 12 readings and average for foot-candles.

\[
\text{Lumens} = \text{average foot-candles illumination} \times \text{sq. ft. area of room}
\]

Example: 12 samples totaled 791.1, and the room is 756 sq. ft.

\[
\frac{791}{12} = 65.92 \text{ foot-candles}
\]

\[
65.92 \times 756 \text{ sq. ft.} = 49839.3 \text{ Lumens}
\]

NOTE: The recommended minimum illumination level of an office desk work zone is 60 foot-candles.

B. The light meter is placed in the room such that the pointer of the meter is deflected to the upper part of the scale. This reading is recorded. Then, a translucent plastic sheet is placed over the meter cell and another reading recorded.

\[
\text{PERCENT TRANSMITTANCE} = \frac{\text{reading with cell covered}}{\text{reading with cell uncovered}} \times 100
\]

Example: 85.2 = light cell covered

\[
94.0 = \text{light cell uncovered}
\]

\[
85.2 / 94.0 \times 100 = 90.6\% \text{ transmittance}
\]

C. Place a piece of white construction paper in a vertical position to measure the illumination that would fall on a wall surface. This reading is recorded. Next, point the cell face of the meter toward the paper, moving it back and forth, until
the reading is somewhat constant. These steps will determine the percent of reflectance.

\[
\text{PERCENT REFLECTANCE} = \frac{\text{reading with cell away}}{\text{reading with cell toward sample}} \times 100
\]

Example: 66.9 = reading away from sample
88.7 = reading toward sample
\[
\frac{66.9}{88.7} \times 100 = 75.4\% \text{ reflectance}
\]

Repeat these same readings by using a mirror to simulate the computer screen.
REFERENCES

American National Standards Institute, Z87 and Z89.


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